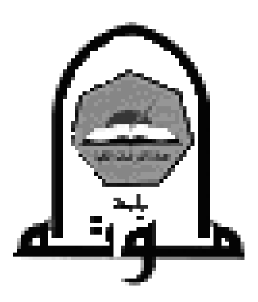


Mutah University
Deanship of Graduate Studies

Forecasting and Management of Water Demand in Al-Balqa Governorate in Jordan

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A Thesis Submitted to the Deanship of Graduate Studies in Partial Fulfillments of the Requirements for the Degree of Master of Science in Engineering Management in Faculty of Engineering.

Mutah University, 2011

الآراء الواردة في الرسالة الجامعية لا تُعبر بالضرورة عن وجهة نظر جامعة مؤتة

بسم الله الرحمن الرحيم



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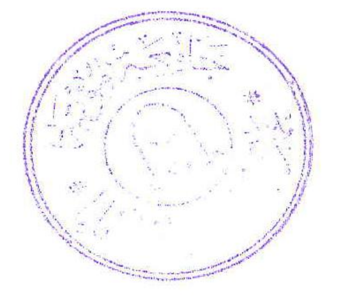
استكمالاً لمتطلبات الحصول على درجة الماجستير في **الإدارة الهندسية**.

القسم: هندسة النظم الصناعية.

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Dedication

To my Parents for their encourage and support , to my Brothers and Sisters and to all of my loyal friends.

Moawiah Ahmad Al-Nsour

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This thesis is conducted at the Deanship of Graduate Studies in Mutah University .

I owe a massive debt of gratitude to my Parents for their support throughout my life. I’m lucky to have their support throughout my career and they will always be a source of motivation and inspiration.

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Moawiah Ahmad Al-Nsour

Table of Contents

List of Tables

List of Figures

List of Appendix I Tables

Abbreviations

Symbols	Definition
WDM	Water Demand Management
MWI	Ministry of Water and Irrigation
WAJ	Water Authority of Jordan
JVA	Jordan Valley Authority
MCM	Million Cubic Meter
SPSS	Statistical Package for the Social Sciences
JD	Jordan Dinar
mm	Millimeter
C□	Celsius Degree
S.D	Standard Deviation
Min.	Minimum
Max.	Maximum

Abstract

Forecasting and Management of Water Demand in Al-Balqa Governorate in Jordan

Moawiah Ahmad Al-Nsour

Mutah, 2011

Water Demand Management is considered one of the issues that must be within the first priorities in Jordan, for its role in the future thinking about the water policies, and setting the appropriate plans that ensure providing the best solutions and alternatives to face serious risks which might face the country in this regard, as Jordan is considered one of the poorest four countries in the world in water.

The model for forecasting water demand has been constructed for municipalities purposes in Al-Balqa governorate using the time series analysis model from historical data for the period (1990-2010). In this study, the historical data is used for water demand forecasting in Al-Balqa governorate, considered are yearly and monthly water consumption and data about socioeconomic factors such as population, improving the standards of life, climatic factors such as yearly and monthly precipitation and monthly temperature, as the forecasting was connected with these independent factors by using the statistical package for the social sciences (SPSS). The historical data can be employed by time series model of monthly municipal water use, for the periods (1990-2010) to verify the model, so the results give the model sort of reassurance to predict future water demand.

The current study employed cascade model in the analysis of historical data, to predict future water demand for the period (2011-2020).

The study found that the increasing of population which will reach 545010 inhabitants in 2020, and the increase in temperature degrees are behind the large demand of water in the future which will reach 55.62 million cubic meter in 2020, which was 27.69 in 2010.

The study recommended the necessity to intensify the managerial procedures to avoid such difficulties that face water sector, through various methods and means such as employment of media and awareness of citizens about the importance of preserving water, limiting its depletion and encourage birth regulation, in addition the coordination between both public and private sectors to exchange the efforts for using the best managerial and technical procedures in order to achieve the water security on the country's level.

ملخص

التنبؤ وإدارة الطلب على المياه في محافظة البلقاء في الأردن

معاوية أحمد النسور
جامعة مؤتة ، 2011

تعتبر إدارة الطلب على المياه من المواضيع الجديرة بأن يضعها المسؤولون في الأردن في صدارة أولوياتهم ، لما لها من دور في التفكير المستقبلي لراسمي السياسات المائية ومعدّي الخطط بما يضمن توفير أفضل الحلول والبدائل لمواجهة أخطار جدية تواجه الأردن في هذا المجال ، سيّما وأن الأردن يعد من أفقر أربعة بلدان بالعالم مائيا.

إن الغاية الأساسية من هذه الدراسة هو التنبؤ بالطلب على المياه وللأغراض المنزلية في محافظة البلقاء للفترة من (2011-2020) عن طريق استخدام تحليل السلاسل الزمنية. إذ هدفت الدراسة إلى التعريف بواقع المياه في محافظة البلقاء ، ومدى استخدام أفضل الوسائل والإجراءات الإدارية المختلفة التي من شأنها ترشيد استهلاك المياه والحد من هدرها واستنزاف مصادرها ، وخاصة أن الأردن باتجاه أزمة حقيقية للمياه ، والذي سيفرض تحديات جديدة على هذا القطاع في المستقبل .

لقد تم العمل على بناء نموذج تنبؤي للمياه باستخدام تحليل السلاسل الزمنية، عن طريق البيانات التاريخية والتي تتعلق باستهلاك المياه سنويا وشهريا للفترة من (1990-2010)، وبيانات ذات علاقة بالعوامل الاجتماعية والاقتصادية كالنمو السكاني وتحسن مستوى المعيشة وعوامل مناخية كمعدل هطول الأمطار ودرجات الحرارة ولنفس الفترة (1990-2010). إذ ارتبط التنبؤ بتلك العوامل المستقلة وباستخدام برنامج التحليل الإحصائي (SPSS) تم تحديد معاملات الارتباط بين المتغيرات المستقلة والطلب على المياه، حيث تم استخدامها للتنبؤ بالطلب على المياه للأغراض المنزلية للفترة من (2011-2020). حيث تم العمل على اختبار دقة النموذج التنبؤي للفترة من (1990-2005) ، والعمل على برهنة النموذج التنبؤي للفترة من (2006-2010) ، حيث أظهرت النتائج توافقا بين البيانات التاريخية والتي تتعلق باستهلاك المياه وبين القيم المحسوبة باستخدام نموذج تحليل السلاسل الزمنية ، إذ يعطي النموذج نوعا من الطمأنينة للتنبؤ بالطلب المستقبلي على المياه.

وقد خلصت الدراسة إلى أن النمو السكاني المتزايد والذي سيصل إلى 545010 نسمة عام 2020 وارتفاع درجات الحرارة وراء الطلب الكبير على المياه في المستقبل، إذ سيصل إلى 55.62 مليون متر مكعب عام 2020 .

وأوصت الدراسة بضرورة العمل على تكثيف الإجراءات الإدارية لدرء هذه المصاعب التي تواجه قطاع المياه، من خلال العديد من الطرق والوسائل كتوظيف الإعلام وتوعية المواطنين بأهمية المحافظة على المياه والحد من استنزافها والحث على تنظيم النسل إضافة إلى التنسيق بين القطاعين العام والخاص على تبادل الجهود من اجل استخدام أفضل الإجراءات الإدارية والفنية بما يحقق الأمن المائي على مستوى الوطن .

Chapter One
Introduction

1.1 General Background

قال تعالى:﴿ وَجَعَلْنَا مِنَ الْمَاء كُلَّ شَيْءٍ حَيٍّ ﴾ صدق الله العظيم. (سورة الأنبياء آية رقم 30)

Water is one of the most important natural resources and plays a key role in the growth of all economic sectors. Jordan is one of the Arab countries that suffer from the problem of water resources , it is considered one of the four most water stressed countries in the world and it is located in an arid to semi-arid zone ;weather conditions are severe; and variation in related hydrological parameters such as rainfall, runoff, and evaporation is wide. They vary from day to night, from summer to winter, and from one year to another.

The combination of water scarcity and increasing water demand have mounted pressures on non-renewable aquifers in Jordan and intensified its dependence on shared water resources with its neighbors. Securing a reliable supply of water adequate in quantity and quality is one of the most challenging issues facing Jordan today. There is a strong belief that no single action can address the water shortage but many actions are needed to increase overall water availability so that future water needs can be met.

The efficient use of water, reallocation among uses and sectors, and establishment of good water governance are among the measures, that could be implemented to reduce the imbalance between demand and supply in Jordan. It is imperative to understand and estimate the relationship between the demand for water in agriculture and the price charged per cubic meter.

This study examines existing water problems in Al-Balqa governorate and makes appropriate recommendations for alleviating some of the ever-increasing gap between water demand and water supply , and to predict the future water demand for municipality sector for the period (2011-2020), to examine the availability of water uses in Al-Balqa governorate, followed by an analysis of main water issues facing the governorate at present and future.

1.2 Importance of the Research

The importance of this study, as a result of a limitation of water resources and increase of water demand, due to increase of population growth. The trend will be toward the management of water demand as the water demand management procedures are one of the most important elements access to the optimal use of water resources.

1.3 The Research Problem

The main problem that faced by Al-Balqa governorate is a shortage of water, and the fluctuation of precipitation in Al-Balqa governorate is one of the most important factors affecting the water statement, in addition to lack of awareness among the population regarding to the use of water for drinking and irrigation. All of these factors caused by lack of knowledge on water issues, where it is clear that the biggest challenges facing the water sector in Al-Balqa lies in the growing gap between supply and demand, which leads to an increase in water shortages, caused by the limited of water resources, noneconomic domestic use of water and impact of low fees on the water demand in municipal, agricultural and industrial sectors.

1.4 Al-Balqa Governorate

1.4.1 Location and Area

Al-Balqa Governorate is located in the western part of the Kingdom with an area (1191 km^2), thus constituting 1.2% of the total area of the Kingdom .Al-Balqa governorate location has an average location between the governorates of the Kingdom. There are many good quality basic services in the governorate such as health areas, cultural centers, sports and its main activities are concentrated in agriculture, especially in the Jordan Valley and its affiliates. Al-Balqa governorate enjoys a strategic and developed location in Jordan, where it is only 30 km from Amman, which is the closest to the capital while it is 350 km from Aqaba, (Al-Balqa Governorate, 2006).

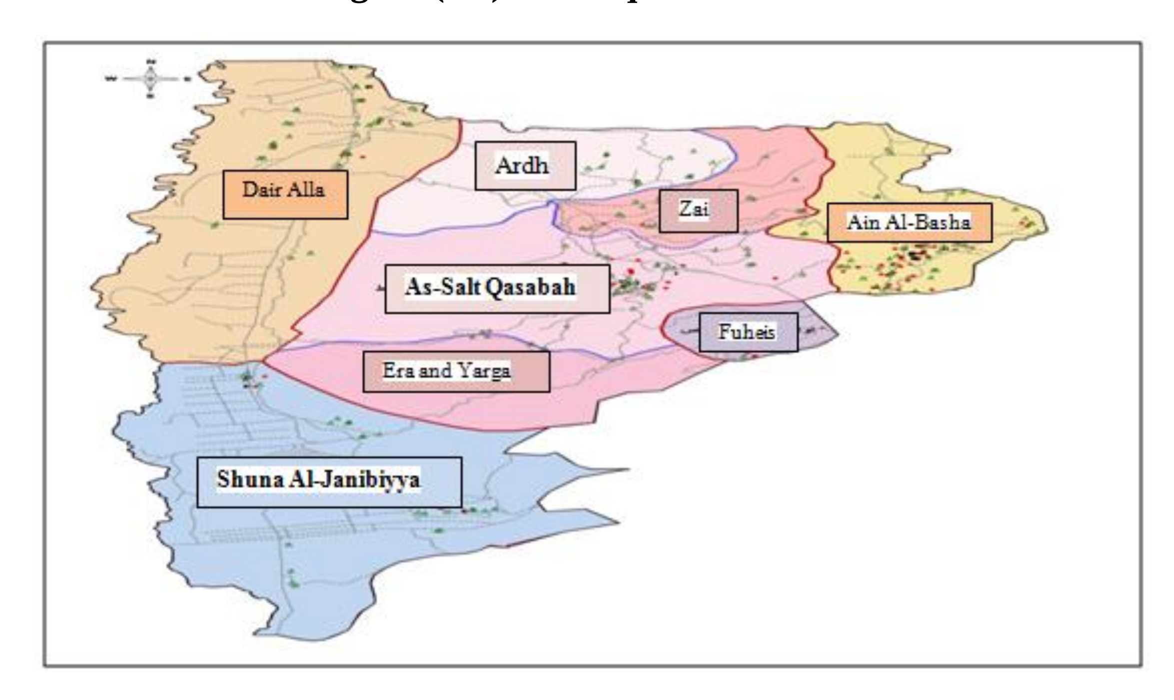
1.4.2 Climate and Terrain

The governorate characterized by maintaining the diversity of climate and terrain where it is divided into two semi-equal divisions: the highlands and the Jordan Valley. The Jordan Valley downs to reach (424 m) below sea level, and the mountains reach a height of (1130 m) above sea level, where high areas have a rainy climate, cold winter and mild summers and average precipitation (600 mm), while the low areas(the Jordan Valley) are characterized by moderate temperatures in winter, high temperatures in summer and the average rainfall reaches (150-200 mm). The climate gives the governorate the advantage of maintaining agricultural diversity throughout the year, as well as tourism importance in both seasons; winter and summer. The water network almost covers all communities in the governorate where its feeding comes from 31 working artesian wells. (Al-Balqa governorate, 2006).

1.4.3 Administrative Divisions

Al-Balqa governorate administratively divided into five districts, as shown in figure (1.1) which are , As-Salt Qasabah which is followed by three districts which are: Ardhah , Era, Yarga, Allan, Zai, Shuna Al-Janibiyya, Dair Alla, Ain Al-Basha, Fuheis and Mahis.

Figure (1.1) Al-Balqa Governorate



The governorate includes nine municipalities, namely:

1. Greater Salt Municipality
2. Municipality of Arda Aljadedah.
3. Municipality of Ma’di Aljadedah
4. Municipality of Fuheis.
5. Municipality of Mahis.
6. Municipality of Ain Al-Basha Aljadedah.
7. Municipality of Dair Alla Aljadedah.
8. Municipality of Middle Shunah.
9. Municipality of Sowayma.

1.4.4 Demographics

The number of population in the governorate in 2010 was estimated to reach about (409500) inhabitants, representing 6.7% of the total population of the Kingdom which is estimated for the year 2010 (6.113 million).The average number of family members in the governorate (5.8), the population density in the governorate is about 365.5 people / km^2 , the population who are living in urban areas of the governorate are about

66.9% of the total population of the governorate, (Department of Statistics, 2010).

1.5 Research Objectives

The following objectives are related to the present study :

1. To understand the actual water demand in Al-Balqa governorate and its problems related to water scarcity.
2. To model the water demand in Al-Balqa governorate using time series analysis model, using measured data for the period (1990-2010).
3. To predict future water demand in Al-Balqa governorate using the resulted time series analysis model for the period (2011-2020).
4. To study the effects of population growth , average income , rainfall and temperature on water demand in Al-Balqa governorate.
5. To present future water demand management practices and policies in Al-Balqa governorate.

1.6 Methodology and Tools

The following will be implemented in the present study :

1. Review previous literatures on the subject and knowing the state of water in Al-Balqa governorate.
2. Collecting data related to population growth, yearly and monthly water use, maximum monthly mean temperature, yearly and monthly precipitation and the annual income per capita in Al-Balqa governorate.
3. Conduct time series analysis modeling aiming to obtain a model predicting future water demand.
4. Discuss methods and implementations for water demand management.
5. Conclusion and recommendations.

Chapter Two
Background Review

2.1 Introduction

2.1.1 Water Resources

Water is considered one of the most important natural Resources that are related to life and the survival of humanity and all its socio economic activities in the various agricultural and industrial fields, water is the backbone of life and its most important element. (Sanhoob, 2006).

Water covers 70% of the globe. It's quantity is fixed and does not change with the passage of time, however, it is renewed continuously during certain period of time, specified by the hydrological cycle. In spite of this large percentage of water which covers the globe, the human beings benefit by not more than 0.01% of total available water. The quantity of water in the globe reaches 1360 million Km^3 in the oceans and seas, and 37 million Km^3 frozen in the both poles, 8 million Km^3 ground water in places not accessible and 0.126 million Km^3 in the lakes and rivers and in the other forms which the human beings can benefit from. But the fresh water is estimated at 34 million Km^3, which shows that the fresh water on the land consists 2.5% of the total water, this means that 97.5% of the global water stock is salty water that consists oceans and seas. (Kadodah, 2002).

Any one looks thoroughly at these percentages will find that fresh water, although it consists only 2.5% of the available water on land, it is a huge quantity and its stock is very huge. Although 69% of fresh water is not available for investment which represents a cover of ice that covers the both poles, while the ground water consists 30% of the total stock of fresh water, the rivers and lakes consist 0.66% of the global water stock. The stock of ground water helps the human beings to overcome period of dry weather, but it depends in the first place on the renewable water. (Kadodah, 2002).

2.1.2 Water Resources in Al-Balqa Governorate

All institutions, especially those concerned of water should set up the procedures, conduct the various studies, provide the methods and tools that preserve water, limit the lack of provision, bridge the gap between supply and demand in order to obtain a good water situation covers the population demand for the various uses including, industrial and domestic, in addition to reduce the water losses and replace the worn old network with a new one. Improvement of socioeconomic situation and increase of population are among the main factors that influence water demand in Al-

Balqa governorate in addition to the environmental factors, and rainfall fluctuation from year to year.(Raddad, 2005).

The amount of annual water transferred from water treatment plant in Zai in Al-Balqa governorate to Amman arrives 90 million cubic meter, which leads to lack of water provision in Al-Balqa governorate and reduce the per capita share of water, so, the ministry of water and irrigation put a project concerned with water transfer from Al Zarah- Main area (south of Al-Balqa), at an average of 40 million cubic meter annually to Amman, which reduces the pressure on pumping from Zai plant and increase the daily per capita and water prevision in the governorate and reduce the gap between supply and demand.(Al-Balqa governorate, 2006).

2.1.3 Water Situation in Al-Balqa Governorate

The main problem, which Al-Balqa governorate suffers from is the lack of available water for the purposes of drinking and irrigation. The daily per capita share of available water is specified at 107.1 liter after deducting the losses of water which were equal to 37% of the water provided by water net works in 2010. (Ministry of water and irrigation 2010), where the used water reaches 150 liter per capita daily. Number of family members in the governorate arrives 5-8 individuals, and leads to consuming water in large quantities, and leads to imbalance between supply and demand on water taking into consideration that supply of water through water networks occurs once weekly for 24 hours. Additional water comes from licensed and unlicensed wells which creates of non rationalization of water. The lack of coordination programmed between the civil society institution that relate to water management, which turn leads to overlapping of responsibilities and to bad water planning. (Al-Balqa Governorate 2006).

In regard with the natural reality of water at Al-Balqa governorate, it is necessary to set up programs, plans and policies that can preserve water and distributing it in the ways that suit of various needs of people, as some of people considering water resources an unlimited and not exhausted natural resource that can be used without a legal or scientific controls. The increase of population and technological progress increases the average of water consumption and the competition for water uses for different purposes. (Al-Balqa Governorate 2006, Jasem 2009).

Surface water and ground water are considered one of the major components of water resources in Al-Balqa governorate, and the rainfalls are considered the main source of water which characterized by high rates in Al-Balqa governorate compared with the other governorate which amount in average annual to 600mm, this good average of rainfall in Al-Balqa governorate helps in provision of irrigation water with the required

quantities, as this rainfall is considered the main provider of surface water and ground water to be utilized specially in summer.

The process of harvesting rainwater by citizens in winter from the roofs of their houses, is one of the important processes to provide water in summer for various home uses after assembled in special tanks, in addition to reuse of waste water after treatment for irrigation purposes, which is some of these water comes from Kherbat Al-Samra waste water treatment plant. (Al-Balqa Governorate & Administrative of Water by Al-Balqa Governorate 2006).

Al-Balqa governorate depends mainly on ground water and water comes from zai treatment plant of drinking water. The different averages of rainfall from one season to another consist a major problem that affects water resources, in addition to lack of awareness among citizens about use rationalization of water, increase the efficiency of use, using the best methods and stopping the water losses.

Water situation in the governorate shows that the great challenge that faces Al-Balqa governorate is the balance between the supply and demand of water in the different methods and means available, in addition to the problem of water losses which is estimate at 37% in 2010, (MWI, 2010) and the necessity to reduce such ration by repair of worn water systems and control distribution and mechanism and detect thefts, in addition to reduce the use of ground water especially for irrigation purposes.

2.2 Types of Water Resources in Al-Balqa governorate

2.2.1 Traditional Water resources

The traditional water resources are considered one of the most important water resources necessary to satisfy the various uses, because they do not need any treatment as in the non conventional resources.

2.2.1.1 Rainfall Water

Al-Balqa governorate depends on the ground water and surface water as a major resource of water in the governorate. The rain water is main tributary of it. However, the impact of this factor is unstable environmentally in Al-Balqa governorate, as the average of rainfall in the governorate is 600mm annually in the highlands and 150mm in the Jordan Valley. Residents depend on such water for irrigation – especially after the process of harvesting water during the winter to be used in summer. Additionally, 20% of the population depend on harvesting the water in the winter to fill the wells for home use. (Al-Balqa Governorate & Administrative of Water by Al-Balqa Governorate 2006).

2.2.1.2 Groundwater and Surface Water

Surface water, is the water formed by rivers, springs, and valleys, in addition to floods water in winter, and considered one of the important water resources. It depends on the average waterfall in winter and feeds the groundwater that is stored in the ground and found in the deep rock layers in large amounts, (Ibrahim, 2000), it is the water that leaks into the ground from the rain water or ice melting or part of the leaked surface water, it is extracted by digging wells. The ground water is also found in natural reservoirs distinguished it from surface water.(Al-Atrash, 2009, IDRC, 2009). Such reservoirs need large amount of capital for their building, and after wise to be extracted and used for the various home and industrial purposes. (Ibrahim, 2000).

2.2.2 Nonconventional Water Resources

Due to the use of surface water and depletion of ground water, convictions generated with the concerned parties of the specialists concerned parties to find new methods and means to limit the depletion and upgrade the use through new non conventional water resources for the various uses. In addition to the increase of the groundwater pollution and the increase in its salinity and low level of quality which is considered one of the most important challenges facing the reality of water in Jordan, (Raddad, 2005). If such water behaviors continue, they will lead eventually to lack of water for the drinking purposes and the other uses, in addition to the increase in the cost of ground water extraction from their reservoirs, which will impact the state treasury. Therefore, the successive governments attempted in all available means to find solutions for using another water resources, different from the traditional resources such as reuse of the treated water, which is considered one of the most important contributor, which will participate in covering the various water needs, and will lead to increase the available water and to reduce the provision defect, in order to bridge the huge gap between supply and demand, especial for industrial and agricultural sectors. (Al-Halasah &Ammary, 2006).

2.2.2.1 Treated Wastewater

Due to the rapidly increasing number of population, and the social and economic development in the kingdom in general and Al-Balqa governorate in particular, where number of population in the governorate according to the report of the general statistics department for the year 2010 reached (409500), the amount of waste water in the governorate will increase, therefore, the ministry of water and irrigation constructed three treatment plants to treat the

waste water in the governorate, namely, salt treatment plant, Baqa'a treatment plant and Fuhais treatment plant. The main purpose of constructing waste water plants is concentrated around environment protection and protecting ground water and surface water from pollution and upgrading the health level of the population, in addition to providing new water, resources can be used for various purposes,(Jaber&Muhsen, 2000).

Treated waste water is one of the additional water resources which are classified as non conventional water resources. The well treated waste water is considered an important water tributary stream that support the conventional water in order to cover the shortage of water provision and to reduce the gap between supply and demand.(Arabiyat, 2002).

Treatment of all the waste water produced by Amman and Al-Balqa governorate is conducted for reuse in the Jordan valley. The waste is treated in three treatment plants in the urban centers in Al-Balqa governorate , Al-Salt, Al Fuhais and Al Baqa'a. The proportion of Salt in the treated water is the large problem, where the percentage of salinity in this water is higher than the normal level, as a result of the low average of home use, in addition to that the technology used in treatment of waste water allows evaporation amounts which increases its salinity, and this is a problem facing farmers in the efficiency of the treated water for irrigation purposes. (IDRC, 2009).

The gray water which is resulted of home use, is considered a main tributary of water for non households purposes. Where it is assembled in special tanks to be treated later on, and reused according to the most recent technological methods and by the multi processes in order to arrive to the suitable water quality for the non domestic various uses. (Macklin, 2003).

2.2.2.2 Water Harvesting

Due to the increase of demand on the conventional water resources especially the groundwater and the extreme dragging which influence this water source, the water sector institutions sought to activate the role of water harvesting and using the water rain in winter. This helps in rationalization and supplementing the water resources.

Constructing water reservoirs to collect water rain in each new building and in the schools, mosques and hospitals will lead to storage of water rain from the surfaces in order to use such water rain from the surfaces in order to use such water in summer for

various purposes,(Bayaydah, 2008). Therefore, the attention to water harvest increased, especially by means of the methods that reduce the use of non-domestic or even the irrigation of home gardens or public gardens at the schools and hospitals, etc. Therefore an urgent need to benefit from rainwater a rose through water harvest and use of water to fill the shortage of water supply. (Aweys & et al, 2002).

2.2.2.3 Dams

The dams in Jordan are considered of the important facilities of water to be utilized for the needs for different purposes as irrigation, especially in the Jordan Valley. There are four sources feeding dams reservoirs, namely, precipitation, surface water, groundwater and wastewater treatment. There are three dams in the governorate provide water for agricultural purposes or groundwater recharge. Table (2.1) below shows the distribution of dams in Al-Balqa governorate.

Table 2.1 The Distribution of Dams in Al-Balqa Governorate*

Dam	Type of dam	Its aim	Total storage Capacity/MCM
Al-Kafreen	Earth fill	For irrigation and recharge ground water	8.5
Wadi Shoaib	Earth fill	For irrigation and recharge ground water	1.43
Al-Karamah	Earth fill	For irrigation	55

*(MWI).

2.3 Water Treatment Plant in Zai

Zai plant for drinking water treatment is considered one of the biggest water treatment plants in Jordan. It feeds the capital Amman with 45% of its drinking water needs and it provides Al-Balqa governorate with about 26% of its water needs and Salt with about 50% of its water needs. The amount of water transferred from water treatment planting Zai in Al-Balqa governorate arrives 90 million cubic meters, which leads to lack of water provision in Al-Balqa governorate and reduce the per capita share of water, (Abuhamoor, 2009). Zai plant consists of two treatment plants with a capacity reaches 125 thousand cubic meter per day, provided with water from three water resources, yarmouk river by 40%, Tabaria lake 35%, and

Al-Mkhaibah wells 25%. The above mentioned three resources pour eventually in King Abdullah channel, where they go 70km in an open channel from the north towards the south in an area called Al-Sawalhah, where water is pumped from Al-Ma'khath plant on the channel in addition to the other water resources, such as Abu-Al – Zeeghan wells that are located near the lift Plant no (1) at a level of 235 under the sea level, to the Zai plant at a high of 880 on above the sea level, where water is pumped through five lift plants by transfer lines with a diameter of 1200 mm in order to be treated. These lift plants are operated automatically, and the level of water is controlled through the control systems that exist in Zai plant in order to pump the treated water from the plant into Dabouq reservoir at 1035 high, and to be distributed to the water network in Amman. (Melkawi & Shiyyab1998).

The process of water purification is not an easy one, but it requires many stages, in Zai plant for drinking water treatment water purification is conducted through many physical and chemical in order to produce the highest quality of water through many control methods that aim at the tight control of the water that comes to the plant from Jordan valley authority. The plants is consisted of 12 control point facilitates water control process each two hours. Such control of water quality goes through the main reservoirs and the distribution networks and the various wells at the aim of knowing the extent of the water compliance with the Jordanian standards and control of the surface and ground water in regard with its chemical and microbiological standards and reviewing the various water resources before completing the treatment processes, in addition of building databases of the data concerned with water in order to refer to them when they are needed and the lab tests that are conducted to the water before it is pumped to ensure its conformity with the specifications. (Melkawi & Shiyyab1998).

2.4 Water Supply and Distribution

Water is the base of life and can not be abandoned in any way. Therefore, according to these basis came the importance of water as one of the most important commodities needed by the residents, which motivated many countries to find the various water resources to provide water for all segments of society and to all its sectors.

Finding new non-conventional water resources, helps in preserve water and rise the use efficiency, such as treatment of waste water and using it in agriculture as one of the non conventional methods to provide water and to close the growing gap between supply and demand. Therefore all the responsible sides of water management in Jordan worked for providing water in all possible methods for all the governorates. Because Al-Balqa governorate is the main pivot of this study, so that the

governorate water department took many procedures that preserve the quality of water network prequalify it, renew it to reduce the lost water to upgrade the use efficiency to provide water for all areas. Therefore, providing water for all sides is an important base in any country in order to arrive to the highest level of providing the basic services to the citizens.

The process of water provision in Al-Balqa governorate is one of the most important priorities of the governorates water department, so the concerned sides worked for providing water in all the possible means from the various sources, either the surface sources or ground sources in order to be pumped through the different distribution networks and to the various parties whatever are their consumption style, either home consumption, or industrial consumption, although the pricing determines the way of distribution, i.e., each sector has a special water pricing.

Water supply in Al-Balqa governorate is different from one year to another because of many basic factors, the increase of population in the governorate is the most important factor in mater provision in addition to some other factors which influence the water supply such as the rising of life standards, the high temperatures, all of these factors increase the demand of water, which requires an increase of supply rates of water. Table (2.2) shows the annual water supply in MCM for the period (1990-2010) as measured by WAJ for domestic use and industrial sector. The water data in table together with the population will be used in the present study as part of the required data. In 1990, the governorates water supply for domestic purposes was 13.66 million cubic meter, until 1995 this quantity was increasing, and the amount of water supplied reached 22.19 million cubic meter in 1995, while in 1996, the water supplied decreased to 20.96 million cubic meter, and continued to decrease until 2001, which reached 16.66 million cubic meter, and this generates a question about the decrease of water during that period and its reflections on the daily per capita of water, with the increase of population number and the decrease of water supply. From 2002, supply of water started to rise, until it reached in the last year of the study's years to 27.69 million cubic meter. Because of the water losses, the water administration in the governorate worked for reducing the losses of water in various ways, therefore, we find that the losses ratio decreased gradually during the study's years with some variation from year to year, either increase or decrease, as the percentage of lost water was 56% in 1990 and reached 37% in 2010, which is a good percentage, which will lead to the increase of per capita share of water in the coming years with the increase in population.(MWI, 2010).

Table 2.2 Water Supply Data for the period (1990–2010) for Domestic Uses

Year	Population*	Water** Supply MCM	L/Capita/day
1990	231315	13.66	162
1991	246855	14.31	159
1992	256395	16.97	181
1993	266330	21.08	217
1994	276100	22.2	220
1995	284400	22.19	214
1996	292300	20.96	196
1997	300500	20.66	188
1998	308400	20.96	186
1999	316000	19.53	169
2000	325400	17.92	151
2001	333500	16.66	137
2002	341600	20.16	162
2003	350400	19.88	155
2004	356000	22.12	170
2005	367200	23.27	174
2006	375200	23.54	172
2007	383400	23.81	170
2008	391900	23.38	163
2009	400600	25.2	172
2010	409500	27.69	185

(*Department of Statistics,** WAJ)

2.5 Literature Review

The following is a brief of literature review on the subject of the present study.

Hambiraa ..et al.,(2011), " Water Demand Management in Botswana: Reflections on the latest review of water ". This study aimed at putting significant efforts in the integrated management of the water resources at Botswana area in South Africa, in order to shift from the traditional methods of the general demand on water to a qualitative method , by setting a pricing policy for water and using the administrative techniques of the water recourses and the economic tools to manage water in a manner that does not require using these tools completely , but putting them in the middle frame of managing demand of water. Results of this study are represented particularly in applying the economic tools as the main element of managing the demand on water. It is one of the important

methods in addition to following the integrated management of water demand, and using the various methods to manage the demand on water such as harvesting the rainfalls and recycling the water, but with setting some legislations for privatization of some services and restructuring the taxing tariff for water and to coordinate with all parties to insure the no conflict between the interests of extending these services.

Abdallah,(2010),“ Trend in the Growth of Water Demand Management Facilities in Jordan’s Tourism Sector ”. This study aims at establishing a model to study the differences in water use. The study’s samples included (14) city and touristic areas in Jordan in 2007. The model used the various statistical methods, and the correlation of the general consumption of water with the seven levels of consumptions of the study. The study also covered the consumption types and the changes that occurred on them in the purpose of knowing their nature and to predict the future needs of water for the touristic activities in Jordan. The importance of the study is represented by the existence of (4) main changeable factors in the touristic consumption styles, such as the rate of occupation at the touristic organizations and number of rooms and number of tourists, which led to explaining the extent of variance of water consumption styles in the study’s area at rate of 89%, and the results of this study showed that the future demand on water for the touristic purposes is increasing, and it will arrive (10) MCM in 2020, and the study recommended to take many procedures and practices in the water demand field and rationalizing the consumption and increasing the awareness and educating the citizens to rationalize their consumption of water and increasing the use efficiency, in addition to using the present techniques in order to provide water and reuse of treated water in the green areas of the touristic institution.

Mohamed & Al-Mulla, (2009),“ Water Demand Forecasting in Umm Al-Quwain (UAE) Using the IWR-MAIN Specify Forecasting Model ”. This study aimed at forecasting the demand on water for the future 25 years in Umm-Al Quwain emirate which is located in the northern part of the United Arab Emirates, by using the IWR- MAIN software through database concerned with the annual consumption of water since 1980, and the monthly consumption since 2000, in order to arrive to a mathematical model can be used to predict the water reality in the future. Consumption forecasting was connected with three different independent variables concern the residences of Umm Al- Quwain emirate, average of degrees of temperature, average of rainfall. Results of the study showed that number of population is the most important element and the main variable that affect the average of water consumption in the Emirates. Many standardizing methods have been implemented on the available data by using the analysis statistical program as SPSS to estimate coefficients that affect on water use, such coefficients are used in the second period to

predict the water consumed and compared with the real use. Using the standardization approach for the available data and making a model leads eventually to arrive to a forecast of water with decreasing the difference between the real demand and the expected demand. Many scenarios have been used to forecast the demand on water in Umm-Al – Quwain, one of the scenarios resulted in that it is expected an increase of 50% on water demand in 2015, in addition to the need of double of the current demand on water before the beginning of 2025, as a result of increase of population due to the increase of migrations rates to the Emirate because of the new developments.

Abdo,(2009),“ Management Evaluation of Water Supply in the Nablus City , Using (WEAP) ”. This study aimed at evaluation of existence of the various methods and options by using the Water Evaluation And Planning (WEAP) software at Nablus municipality, in order to know the ability to bridge the gap between supply and demand. The study’s methodology included collection of the various data about Nablus city and modeling the water resources system in Nablus city by using the WEAP software at the aim of arriving to the different options through which it is possible to bridge the gap between supply and demand. The results of the study showed that the water demand is increasing continuously, as the population is also was increasing over the years of the study. The continuity of this situation will expand the gap between supply and demand. The study recommended with the necessity to find alternative resources to cover the water defect and to exploit the various methods to provide water such as water harvest, and conducting periodic maintenance for the infrastructures in order to control and repair them and lessen the lost water.

Al-Dorgham, (2008), “Adjusting the Irrigation Water Demand Projection Module to be Viable in the Jordan Valley ”. This study aimed at knowing the ability of the water demand management unit and the ministry of water and irrigation to use the various tools that estimate the size of used quantities of water in the agricultural sector, and forecasting the demand on water in the future in the Jordan valley area, at studying the demand on water for some years and forecasting the demand of water, to compare the reality to verify the extent of their efficiency and ability to use the appropriate tools through the data and the calculations. The results of the study showed that the forecasted quantities of demand of water within the various calculation operations are higher than the real quantity according to Konica system (1989), because it takes the crop in its first stages in favor of growth coefficient in, of the usage, in addition to the exaggeration in the quantities of the forecasted rainfall, which lead to the exaggeration of usage and the extent of need for water. This significant difference between the calculated forecasted quantity and the real demand

leads to disequilibrium between the water requirements which we obtain and the real usage of water.

Al-Jaafrah, (2007), " Forecasting of Water Demand for Irrigation in the Jordan Valley under the different of Water Pricing Policies ". This study aimed at controlling the water pricing techniques in order to know the influence of pricing policies on the expectations of irrigation water quantities in Jordan valley, and evaluation of their influence of the planted areas and on the levels of using the water for the agricultural purposes, in addition to studying the influence of some water pricing policies in Jordan valley on the water strategies of demand management such as the awareness initiatives in the governorate, and encouragement of not planting summer plants because they need huge amounts of water through a time program determines the date of water providing. In order to achieve the aims of this study, the researcher designed a form of linear program in order to study the influence of water usage on the agricultural crops types, in addition to its pricing and the relationship between the tariff and usage to achieve the required profits to the farmers, in addition to the prediction of the future way of consumption through four canaries as follows:

1. The influence of the water pricing policy on the way of water distribution and the need of the crops to this water .
2. The influence of the pricing tariff on the specification of the agricultural styles, through their need for water.
3. The influence of autumn planting on water consumption and the net returns of the planted areas.
4. Limitation of the used quantities of water through the competition between the crops and application of the principle of the fair distribution of water.

The study resulted in knowing the extent of the huge impact on water usage and the demand on water through the tariff and using various methods to collect and preserve water.

Alqudah, (2006), " Water Demand Management as a Tool for Bridging the Water Gap of Jordan " .This study aimed at knowing the water resources in Jordan, and at studying such resources and the extent of their availability in order to estimate the future demand on water, in addition to the ability to bridge the gap between supply and demand based on three canaries, and the verification of the ability of the administrative methods for the demand on water to close the gap between supply and demand. And The researcher designed a questionnaire through the management of the social survey, in order to obtain the demographic information for the families such as (the quantity of the consumed water and the social and economic data … etc). The sample of the study included

residents from Irbid governorate who live inside and outside Irbid. The researcher conducted used the necessary statistical programs to analyze the data. The results of the study showed that the average or consuming of water for the governorate's residents who live inside and outside the city in summer season is much higher that winter season, as a result of the increase of degrees of temperature. The study recommended to review the methodology of demand management on water to bridge the gap between supply and demand and to use the best methods of water distributions using the modern technical methods in order to provide water and to increase the usage efficiency, in addition of increasing the awareness of citizens in the methods that are used to rationalize the consumption of water and preserving it.

Hissyan..et al,(2006), " Water Demand Management in Arab Word, Syria as A case Study ". This study aimed at knowing the extent of water resources availability in Syria and their various resources and to study the current status of the available water resources either from the traditional or the nontraditional resources in order to specify the various water needs for all sectors in order to predict the future demand on water, and the ability to provide the water quantities necessary for the various needs. This study resulted in finding the suitable solutions in managing the water such as the pricing policy and rationalizing the usage, in addition to supporting the state's budget in regard of improving the water instructions and their reflection on water provision. While in the agricultural side, a pricing mechanism will be applied for the irrigation water and installment of meters on the used ground wells, in addition to increasing the fees on the water used in industry and increase of the fees on the slides used in water.

White..et al,(2003)," Urban Water Demand Forecasting and Demand Management: Research Needs Review and Recommendations ". This study aimed at conducting a primary review for water demand verification in the urbanized areas in Australia, in order to present main database, will be used in conducting the researches and looking the factors that impact the demand on water, however, from another point of view studying the improvement of the research practices in a wide manner, within a clear methodology to set a database can be used to achieve the required knowledge in this field and to bridge the gap in the data, which will participate in the best administrative procedures in term of managing the demand on water and its future forecast.

Arabiat, (2002), " Water Price Policies and Incentives To Reduce Irrigation of Water Demand in Jordan ". This study aims at studying the impact of water pricing policy to limit and control the extreme use of water and increasing the use efficiency through the idea that pricing mechanism is the only way that can cover the cost of water transportation and distribution. Water pricing in the Jordan valley area is designed in a

manner that provide a complete cover partition of transportation and distribution cost, and it increased the use efficiency for irrigation purposes at a rate of 70% compared with 50% in the last decade, as a tool of control and limiting the demand on agricultural water. This study showed that the pricing policy of water will limit the demand on water and the extreme use of water and decreasing pumping from the ground water, as agriculture is the biggest consumer of water.

Murillo & Barcones,(2002),“ Water Demand Management Policy for Water Supply, Ebro River water Transfer ”. This study aimed at verification of the extent of using the methods used in managing the demand on water as an alternative of the water supply policy, that is the national policy in Spain for the hydrology. It was shown that the policy of managing the demand on water in term of the price tariff of water, whatever it is, does not have a significant impact on limiting the scarcity of water or arranging the usage, but there must be an external support which will provide income and other source of water in order to be able to compensate the lack and provide the various needs. In the agricultural side, some scenarios in regard of managing the demand on water have been implemented, where two scenarios have been used: The first scenario : through which the use of water is observed to limit the extreme use of ground water. The second scenario is related to increase the prices of water in order to calculate the water price with alignment with the international water price. The results of this study are represented by alternative resources of the traditional resources and water desalination and improving the irrigation efficiency.

Savenije..et al,(2002), “ Water as an Economic Good and Demand Management Paradigms with Pitfalls ”. in the Netherlands. This study aimed at reviewing the water pricing methods, because this process is the base of water sustainability and recovery of transportation and distribution cost as the main purpose of pricing, in addition to achieving the justice for usage and dividing the usage slides and pricing, with providing the adequate guarantees to preserve the water resources and preserve the environmental requirements and providing drinking water for all. This study results are represented by the idea that setting a water tariff sends a signal to water users to rationalize the water usage and to limit the water losses instead of the extreme usage of water and the lack of controls.

Department of Environment and Resource Management, Queensland Environmental Protection in Australia. (2000), “ Illustrative Water Demand Management, Plan and Guide for Preparation ”. This study aimed at setting an inclusive plan to manage water demand, and the tools used in order to limit the extreme consumption of water and to provide water and to increase the efficiency of using it as a sub plan among the other administrative plans. This study recommended

many directions through with the principles and tools of water demand are applied. The local governments are responsible of setting the various plans in order to preserve water through them and to increase the usage efficiency and taking the various procedures such as providing the rainfall reservoirs and recycling the water wastes, in addition to providing the methods that limit using water in the industrial operations and the housing devices, including for example : decrease the water flow in lavatories, and increasing the efficiency of the used devices, and finally setting pricing policies for water and restructuring the tariff and observing the water meters and providing financial incentives and the privileges to limit water usage.

Jaber & Mohsen,(2000),“ Evaluation of Non-Conventional Water Resources Supply in Jordan ”. This study aimed at presenting many suggestions and various arrangements that elevate and overcome the water problem in Jordan. Through building the various hydraulic structures and exploiting the groundwater, in order to confront the supply management. In spite of this there is no clear mechanisms to face the challenges of water supply. However, with producing, some procedures for using another water resource such as water desalination and using them to face the water problem, and setting plans and programs to use nontraditional water as a mechanism of water provision and to compensate the shortage of provision and reuse of sewage water and water harvest.

Ibrahim, (2000),**“** Water Demand Management in Jordan Rationalize Consumption and Reduce Waste **”.** This study aims at following methods related to management of ideal water demand, and decreasing the lost water and their influence on the sustainability of water resources. In this way it is possible to preserve water and rationalize the consumption and to attempt to treat the problem of water lack in Jordan and to elevate this problem and to preserve the various water resources. Results of the study showed that the impact of pricing water does not respond to the pricing techniques, because water can be considered inflexible commodity. The study also showed that the rate of lost water in Jordan is very big compared with the global ratios. Therefore, it is necessary to know the reason of water loss and to find methods to repair the worn water networks and to set the organizational plans in regard with the distribution method and to punish the illegal users of water. The study recommended to implement an inclusive methodology in water demand and rationalization of consumption and raising the use efficiency, and decreasing the water loss and setting the water policies and implementing them in the real situations, that are concerned with the demand on water resources and how to manage this demand.

Herbertson & tate, (1999)," Tools for Water Use and Demand Management in South Africa ". This report aimed at knowing the abilities of the various tools and techniques in water demand management and using it effectively in all areas and limiting the illegal consumption of water and to limit the water crisis and decreasing the problems that are related to the water resources. The report was issued by a workshop about management of water demand, was conducted in Harare, Zimbabwe, with the support of the hydrology program and the water resources of the general secretary of the international meteorology in Geneva, Schweitzer land and the department of the united Kingdom for the international development (DFID) and the UNISCO organization. The report recommended with the necessity to raise the awareness of the specialists in the water resources affairs, by managing the demand on water and implementation of the best practices towards executing the tools of demand management on water with providing the necessary materials to be used in operating the hydrological services, in addition to the concern of the nontraditional resources in order to preserve the water resources and managing the demand water to sustain the water resources and not deplete them, in addition to preserve the economic efficiency with the necessity to study the role of the various levels and organizations to support this trend.

Chapter Three
Water Demand Forecasting Using Time Series Analysis

3.1 Water Demand Forecasting

3.1.1 Introduction

The increase of demand on water for various purposes as a result of the increase of population and improvement of the economic standards and life styles. This huge increase on demand is considered one of the challenges that confront those who plan for the future needs.

Therefore, the concerned people tried to forecast the future demand on water, based on the data and the previous information that shows the extent of usage of water, and to specify the available water in the future and how to influence usage of water, (Memon & Butler, 2001).

Forecasting depends on future probabilities based on scientific foundation and previous information through which it is possible to judge the water reality in the future in an approximate manner. However, the probable results give an indication for the expected demand for using water, can be relied on. The main purpose for forecasting is to limit the gap between the water reality and the future usage, in order to enable decision makers to provide the needs and to study the alternatives.

Many factors influence water usage, such as the population ,the economic factors, the weather, the agricultural needs, the life style. Therefore, it is possible to direct the trends of decision makers, in order to take the best decisions through forecasting the various needs of water and the available quantities in the future, to arrive to the best results in the long run in a credible way, (Mays&Tung,1992).

The future needs are connected with the growth in population, which in the basic element, however, connecting this element with consumption only leads to imprecise results in term of forecasting the consumption of water in the future because there are another factors related to the life style progression, and increase of awareness of the consumers especially with the existence of the demographic factor that leads to the increase of population as a result of some disturbances as a result of natural or political events, such as wars, and earthquake and the immigration, which increase the demand on water, and therefore arising of no studied usages. This demographic factor causes the failure of forecasting as a result of sudden and no studies factors or even not planned, (Mays&Tung,1992).

Forecasting the future usage of water leads to development of thinking of decision makers to set alternative methods to provide water resources through the various studies of water reality. Therefore, the future demand on water is evaluated through the changeable circumstances and

sudden and no studies cases, which lead to increase the efficiency of forecasting in the future, (Lawgali, 2008).

3.2 Time Series Analysis

3.2.1 Definition of the time series: It is a set of ordered recorded and observed measures for one variable or more for a certain phenomenon according to the time of its occurrence.

Time series for a certain area according to certain information about a service issue are considered one of the most better and precise methods of future forecasting according to various information for various certain periods of time.

One of the most important time series that are used for forecasting the future, those which are concerned with the demographic and economic issues, and those concerned with the company's profits, through forecasting to know the future situation each year, which reflects the extent of concern and the methods of treating the problems before occurring, (Muhasen, 2006).

3.2.2 Types of Time Series

3.2.2.1 The Continuous and Distinct Time Series

1. The continuous time series:
   It is the series, through which it is possible to measure a reality or a changeable phenomenon during a certain period of time for example (The consumed quantity of water during a year, average annual rainfall, and the increase of population during a year).
2. The distinct time series:
   It is the series through which it is possible to measure a changeable reality or phenomenon, for example (The quantity of water consumed in a certain day out of a series of years), (Jenkins&Reinsel,1994).

3.2.2.2 Point and Non-Point Time Series

1. Point time series: it is measured through the unexpected times (times of occurrence of earthquakes, floods and natural disaster)
2. Non point time series: it is measured through previous and specified times for example (the series of the average of the annual income in the Balqa governorate at the end of 2010). .(Kordi, 2010)

3.2.2.3 Binary and Non-Binary Time Series

1. The binary time series, which accepts only two values, it is used in the electrical engineering and communications. .(Kordi, 2010)

2. The non binary time series, which accepts more than one value, such as number of population.

3.2.3 Elements of the Time Series

1. The general trend.
2. The seasonal changes.
3. The periodic changes.
4. The random or accidental variables. .(Kordi, 2010)

These main elements of time series are significantly affected by the changes in the various communities such as the demographic changes, improvement of the economic status of people, therefore, it is necessary to take them into consideration.(Kordi, 2010) :

3.2.3.1 The General Trend

The time series for a certain phenomenon in the community in a certain period of time might take a trend of increasing or decreasing or both, such as the increasing of the population and decreasing of the learned people. Therefore, the general trend of the time series is one of the most important elements of influence, because they are connected with a sudden and unclear events, but they are connected with a gradual growth or decrease, might be linear or nonlinear (curve), therefore, the changes that occur in the general lead to the following types:

1. The increasing time series: it represents a certain phenomenon, the line represents (the general trend) an observed increasing such as the increase of population in a time unit.
2. The decreasing time series: it represents a certain phenomena's and the line (the general trend) represents a decrease, for example, the decrease in the agricultural lands because of the increase of urban areas.
3. The fixed time series:
   It represents a certain phenomenon, in which line (general trend) represents a stability without any increase or decrease, for example, the quantity of the consumed electric power in lighting of the main streets in the governorate.
4. The time series that is changed in intervals of time:
   It represents a comparative curve for a function such as the comparative curve of a function of degree's, because the series values might be influenced by seasonal or annual issues. For example, the series of wool clothes sales in all days of the year but the increase in winter and decrease in summer.

3.2.3.2 The seasonal changes

They are connected with certain times such as the religions occasions, and holidays, or the beginning of the schooling year in which the sales of a certain commodity increase.

Therefore, such time series are considered a way of influencing the seasonal changes, which might be weekly, monthly, or any fixed period of time.

3.2.3.3 The periodic changes

Those changes that occur periodically with an increase or a decrease within a certain period of time, with some differences in these changes, and they can be measured from the maximum change to the other maximum change within two successive periods of times.

3.2.3.4 The random changes

They occur randomly and in irregular manner, within a certain series of time, such as the changes that might occur during sudden strikes, that cannot be predicted within a short period of time or the natural disasters and wars, which influence the other remaining elements of the time series, because they are connected directly with a previous events.

3.3 Water Demand Forecasting in Al-Balqa Governorate

Time series as previously discussed is a series of observations of the phenomenon and within the specified period of time, and are therefore a set of variables that are studied and used to build a mathematical model through which to predict the phenomenon in the future in a time series of data and previous information is a key element in the estimates of the future and a model that provides important information to decision-makers in order to determine the actions needed to the future, such as predicting the number of the population reflect the demand of water.

The method of time series analysis is a statistical method and very important, as it can provide tools for model selection which can be used to predict future events, such as supply and demand for a particular good or service, adopt the method of time series analysis to monitor the phenomena and to observe changing within a certain time, eventually, to predict the future based on the variables in the time series and on the extent of the change in their growth; so it differs from the traditional method, which takes only two times series, then measures the difference in value between them to build a prediction for the future, without considering the general pattern of the time series itself and the extent of the overall change of those values, (Kordi,2010).

Time series analysis is used to get a forecast from the historical data. In this study, the historical data used for water demand forecasting in Al-Balqa governorate considered are population, monthly and yearly precipitation, annual family income and monthly temperature. So the historical patterns of variations can be employed by time series of monthly municipal water use, thus the historical pattern can be divided into long run and short run components of memory. Long term memory components can be classified into two sub components. First, a trend which indicates the yearly effect of slow change in many issues such as population, annual family income and yearly precipitation. Second, seasonality which indicates the cyclic pattern of variation in water use within a selected year.

The short term components can be classified into two sub components. First, autocorrelation which indicates departures perpetuation for water use from the long term pattern variation. Second, climatic correlation which indicates the effect on water use within exceptional climate conditions (dry or wet year).

The current study employs cascade model in the analyses of historical data , so the cascade model indicate two successive development stages which are involved in transforming monthly water demand using time series analyses by four sequential stages for the development of cascade model, then the following stages are used to forecast water demand in Al-Balqa governorate, (Mays&Tung, 1992).

I. Detrending

1- Identify the trend of annual mean of monthly water use in each year, $Q_a(y)$, and it is related to the variables as population, income and yearly precipitation by liner equation as :

$$Q_a(y)=\eta_0+\eta_1*Population(y)+\eta_2*Income(y)+\eta_3*Precipitation(y) \quad (3.1)$$

Where $\eta_{0,}$ $\eta_{1,}$ η_2 and η_3 are regression coefficients and *y* is year.

2- Subtract trend values obtained from equation (3.1), from the measured data of the monthly water use, $Q_a(m,y)$ to describe the detrending using time series.

$$Q_b(m,y) = Q_a(m,y) – Q_a(y) \quad (3.2)$$

Where $Q_b(m,y)$ is the detrended monthly water use, *y* year and *m* months.

II. Deseasonalization

1- Using the detrended series $Q_b(m,y)$, to determine the seasonality pattern, then it can be done by using the fitting monthly average in $Q_b(m,y)$. the year seasonality can be characterizes by $Q_b(m)$, m=1,2,…,12.

$$Q_b(m,y) = \frac{1}{Y}\sum_{y=1}^{Y} Q_b(m,y) \tag{3.3}$$

Using equation (3.4) to find seasonality

$$Q_b(m) = \sum_{k=0}^{6}\left[a_k \cos\left(\frac{2\pi km}{12}\right) + b_k \sin\left(\frac{2\pi km}{12}\right)\right] \tag{3.4}$$

To find Fourier coefficients it has to use equations (3.5*a-c*)

$$a_0 = \frac{1}{12}\sum_{m=1}^{12}\left[\frac{1}{Y}\sum_{y=1}^{Y} Q_b(m,y)\right] \tag{3.5a}$$

where Y is the number of years = 16

$$a_k = \frac{1}{6}\sum_{m=1}^{12}\left[\frac{1}{Y}\sum_{y=1}^{Y} Q_b(m,y)\right]\cos\left(\frac{2\pi km}{12}\right) \tag{3.5b}$$

for k = 1,2…..6

$$b_k = \frac{1}{6}\sum_{m=1}^{12}\left[\frac{1}{Y}\sum_{y=1}^{Y} Q_b(m,y)\right]\sin\left(\frac{2\pi km}{12}\right) \tag{3.5c}$$

for k = 1,2…..6

And $b_0 = 0$

Remove seasonal pattern from $Q_b(m,y)$ to illustrate the deseasonalized series, using equation (3.3) and (3.4).

$$Q_c(m,y) = Q_b(m,y) - Q_b(m) \tag{3.6}$$

III. Autoregressive filtering

Removal of auto-correlation, based on $Q_c(t)=Q_c(m,y)$, where t =1,2, …T.

$$Q_c(t) = \sum_{i=1}^{I} \Phi_i\, Q_c(t-i) + Q_d(t) \tag{3.7}$$

Where, Φ's are autoregressive coefficients and it can be determined using equation (3.8) through a linear regression analysis.

$$Q_c(t) = \Phi_0 + \Phi_1 Q_c(t-1) \tag{3.8}$$

and using $Q_c(t)$ values from the seasonality to find the residual $Q_d(t)$, where $t = 2,\ldots,192$ in equation (3.7).

IV. Climatic regression

To compute dependence of monthly water use related to time series from autoregressive analysis $Q_d(t)$, then the climatic variables of the same month t where $t = 1,2,\ldots, T$ as

$$Q_d(t) = \sum_{l=1}^{L} \beta_\ell \, x_\ell(t) + Q_e(t) \quad (3.9)$$

Where β_l's regression coefficients and $Q_e(t)$ are determined through a linear regression analysis, using the values of $Q_d(t)$ founded from the auto-correlation stage.

To use cascade time series model to forecast water demand, it is necessary to collect data from the authorities that related to water. So, using the historical data for time period 1990–2005 of monthly municipal water consumption for Al-Balqa governorate, the time series analysis can be built a forecasting model based on the historical data as shown in table (3.1). This model involves four stages in long term components $Q_L(t)$ or $Q_L(m,y)$ and short term components $Q_S(t)$ or $Q_S(m,y)$ reaches to monthly municipal water use in Al-Balqa governorate and it can be expressed as $Q(t)$ for $t = 1,2,\ldots,T$ or $Q_a(m,y)$ for $m = 1,2,\ldots,12$ and $y = 1,2,\ldots,Y$, where t is the month No. from the start of time series to the end of last month T, m is an initial of monthly for each year and y is the begin of years where Y is the total number of years in the study.

Table (3.1) shows the monthly municipal water consumption from January to December over the period from (1990-2005), notice that the monthly water consumption during June to September over the same period is higher than the other months, due to the high temperature and other uses during summer season, and the lowest value of monthly water consumption is at the beginning and end of year due to the decrease of use during winter season. The monthly water consumption from June to September for each year can be adjusted by assuming and adding 25% to monthly water consumption that was recorded by water authority due to the non-recorded water used supplied by private sector.

Table (3.1) Monthly Municipal Water Use in Al-Balqa governorate for the period (1990 -2005) in MCM *

Year	Month	$Q_a(m,y)$	Year	Month	$Q_a(m,y)$
1990	1	0.968		10	1.526
	2	0.742		11	1.291
	3	0.871		12	1.467
	4	0.978	1994	1	1.704
	5	1.033		2	1.701
	6	1.29625		3	1.708
	7	1.36625		4	1.673
	8	1.4825		5	1.861
	9	1.4575		6	2.22625
	10	1.143		7	2.225
	11	1.132		8	2.29625
	12	1.193		9	2.14875
1991	1	1.017		10	1.648
	2	0.866		11	1.433
	3	1.016		12	1.58
	4	1.042	1995	1	1.667
	5	1.212		2	1.506
	6	1.4875		3	1.758
	7	1.48625		4	1.721
	8	1.46375		5	1.888
	9	1.41375		6	2.1925
	10	1.14		7	2.31625
	11	1.161		8	2.23125
	12	1.007		9	2.02375
1992	1	0.87		10	1.731
	2	0.914		11	1.588
	3	1.088		12	1.566
	4	1.22	1996	1	1.372
	5	1.26		2	1.351
	6	1.75		3	1.413
	7	1.7		4	1.5
	8	1.775		5	1.714
	9	1.9		6	2.14625
	10	1.56		7	2.31875
	11	1.52		8	2.28375
	12	1.41		9	2.16625
1993	1	1.666		10	1.679
	2	1.658		11	1.559
	3	1.646		12	1.452
	4	1.592	1997	1	1.359
	5	1.797		2	1.24
	6	2.115		3	1.36
	7	2.12		4	1.556
	8	2.19		5	1.696
	9	2.0125		6	2.20875

Year	Month	$Q_a(m,y)$	Year	Month	$Q_a(m,y)$
	7	2.305		7	1.91375
	8	2.2525		8	2.175
	9	2.17375		9	1.96
	10	1.644		10	1.303
	11	1.469		11	1.245
	12	1.391		12	1.178
1998	1	1.349	2001	1	1.104
	2	1.225		2	0.981
	3	1.347		3	1.274
	4	1.566		4	1.251
	5	1.834		5	1.407
	6	2.425		6	1.7325
	7	2.50875		7	1.7975
	8	2.1775		8	1.86875
	9	1.9525		9	1.7025
	10	1.554		10	1.322
	11	1.525		11	1.1667
	12	1.498		12	1.056
1999	1	1.405	2002	1	1.081
	2	1.238		2	1.067
	3	1.353		3	1.284
	4	1.471		4	1.431
	5	1.617		5	1.63
	6	1.97125		6	2.16625
	7	2.02		7	2.325
	8	2.065		8	2.3625
	9	2.01125		9	2.2775
	10	1.532		10	1.718
	11	1.431		11	1.487
	12	1.419		12	1.334
2000	1	1.143	2003	1	1.248
	2	1.105		2	1.006
	3	1.115		3	1.215
	4	1.374		4	1.317
	5	1.54		5	1.723
	6	1.86625		6	2.22

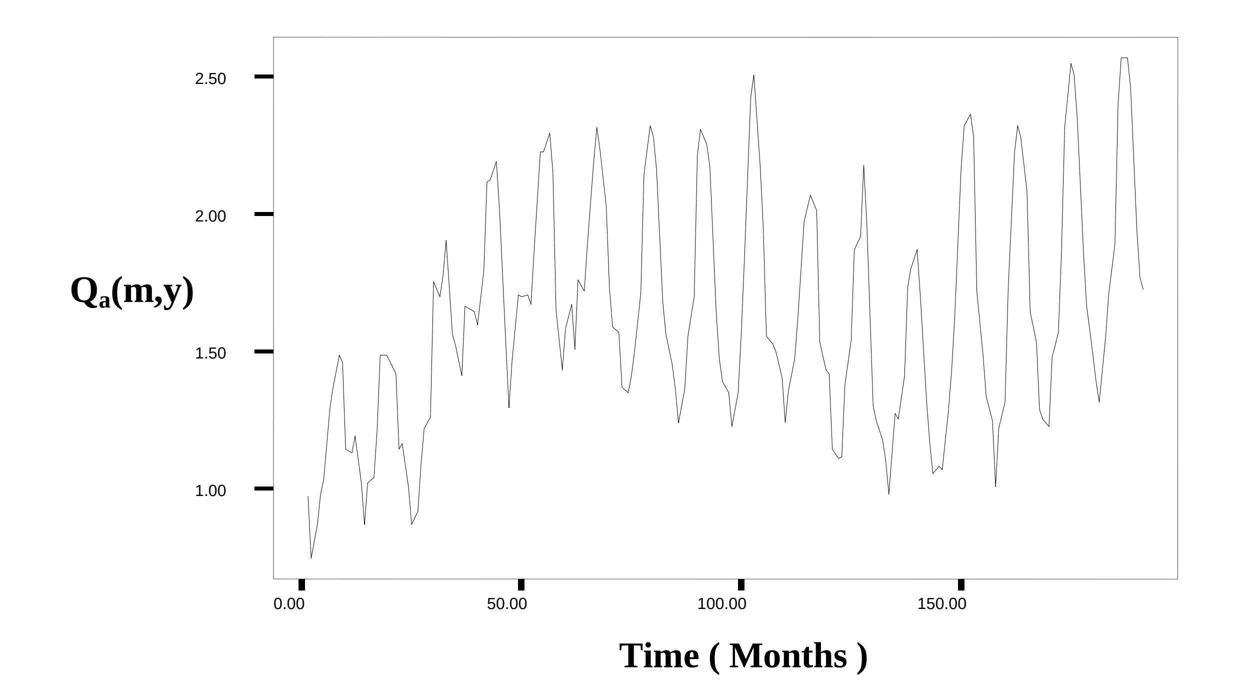
follow

Year	Month	$Q_a(m,y)$	Year	Month	$Q_a(m,y)$
	7	2.32375		10	1.858
	8	2.28		11	1.663
	9	2.08125		12	1.487
	10	1.643	2005	1	1.391
	11	1.536		2	1.313
	12	1.287		3	1.549
2004	1	1.25		4	1.708
	2	1.226		5	1.89
	3	1.478		6	2.3975
	4	1.569		7	2.57
	5	1.868		8	2.565
	6	2.315		9	2.46
	7	2.55		10	1.94
	8	2.50875		11	1.765
	9	2.3475		12	1.726

*(Yearly Reports of MWI for the period 1990-2005)

Figure (3.1) shows the monthly water use for the period (1990-2005) as following, where mean value for $Q_a(m,y)$ is 1.6 and standard deviation is 0.42.

Figure (3.1) Monthly Municipal Water Use for the period (1990-2005) MCM



3.3.1 Detrending

The first stage in developing cascade model is to use detrending analysis, that indicates identifying a trend over year of monthly municipal water use in the historical time series, thus remove estimated trend that founded in historical data to assess the over year water use trend, and that's contained in $Q_a(y)$ representing the annual mean of monthly water use in year *y*. Equation (3.10) can be used to estimate annual mean of monthly water use in all years *y* using historical data.

$$Q_a(y) = \frac{1}{12}\sum_{m=1}^{12} Q_a(m,y) \qquad (3.10)$$

where $y = 1,2, \ldots ,Y$.

Equation (3.10) describes the annual mean of monthly water use $Q_a(y)$ and monthly municipal water use $Q_a(m,y)$ from the period (1990 – 2005), as shown in table (3.2). The minimum value for water use 1.14 appeared in 1990 and maximum value for water use 1.94 appeared in 2005, so the general trend for annual mean of monthly water use $Q_a(y)$ is increasing during the period (1990-2005).

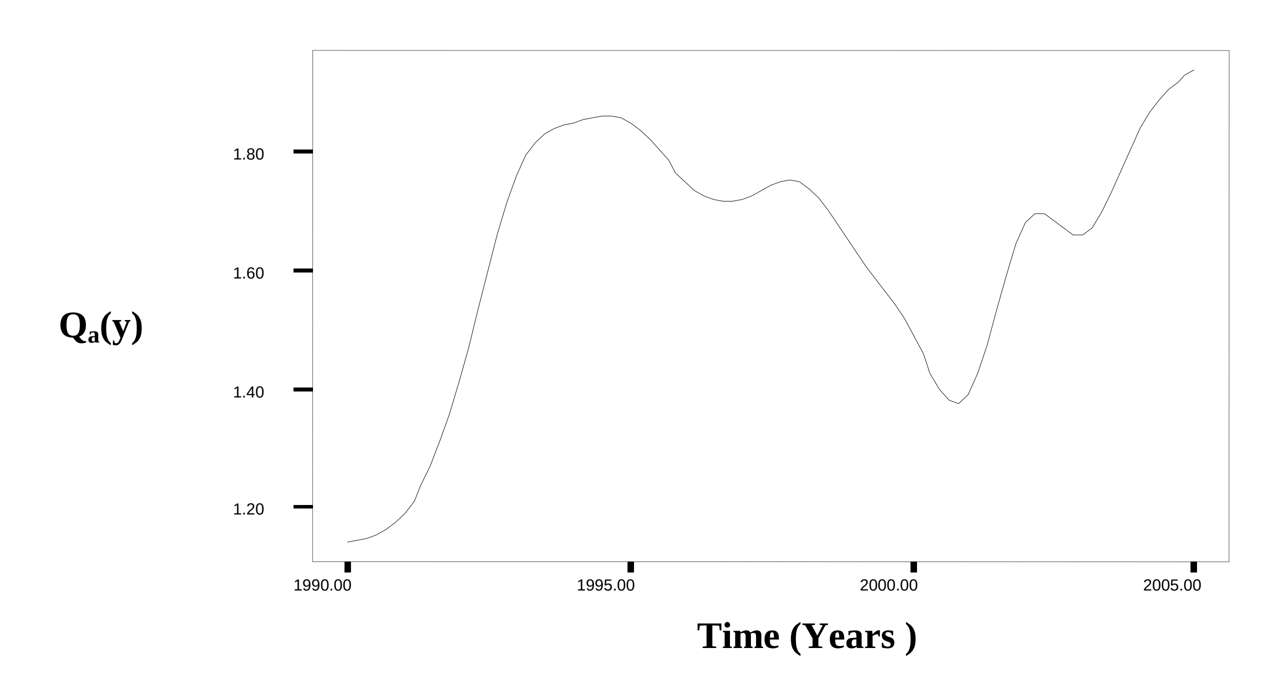
Table (3.2) Total Yearly & Annual Mean of Monthly Water Use

Year	Total annual demand of water MCM*	$Q_a(y)$ MCM
1990	13.66	1.14
1991	14.31	1.19
1992	16.97	1.41
1993	21.08	1.76
1994	22.2	1.85
1995	22.19	1.85
1996	20.96	1.75
1997	20.66	1.72
1998	20.96	1.75
1999	19.53	1.63
2000	17.92	1.49
2001	16.66	1.39
2002	20.16	1.68
2003	19.88	1.66
2004	22.12	1.84
2005	23.27	1.94

*(Yearly Reports of MWI for the period 1990-2005)

Fig. (3.2) shows the annual mean of monthly municipal water use $Q_a(y)$ in Al-Balqa governorate for the period from (1990-2005), it was found that the annual mean of monthly water use in high increase during the period from (1990-1994), while showing the consumption dropped for the years (1995-2001), but from the period (2001-2002) an annual mean of monthly water use was significantly increased, then in the year (2003) consumption dropped slightly, but returned to a noticeable rise in the years (2004 and 2005) because of the population growth. This can be illustrated in the increase of consumption of water from the period (1990 - 1995) due to reasons attributable to high level of population in Al- Balqa governorate, especially given the increase of population caused by the political crises in the region of the Refugees to the Middle East. In (2001) it was slightly dropped since the new law of municipality was issued which implies the necessity of encouraging water harvesting in households and use water saving fittings for reduce of water use.

Figure (3.2) Annual mean of monthly municipal water use for the period (1990-2005) MCM



Consider that long term water use in Al-Balqa governorate is related to socioeconomic factors effects of water use such as population, annual family income and annual precipitation, so the annual mean of monthly water use could be computed using equation (3.1), where $y = 1,2,\ldots,16$. thus the average total annual demand of water is considered the dependent variable $Q_a(y)$ in equation (3.1).

$$Q_a(y) = \eta_0 + \eta_1 * Population(y) + \eta_2 * Income(y) + \eta_3 * Precipitation(y) \quad (3.1)$$

Where η represents regression coefficients, and there are three socioeconomic effects for annual mean of monthly water use, the coefficient η can be estimated by regression analysis using historical data of the annual mean of monthly water use $Q_a(y)$ in table (3.1) and socioeconomic factors in table (3.3) for Al-Balqa governorate from the period (1990-2005). The table (3.3) shows the annual growth of population and annual family income was increasing over the period (1990-2005) but there is a fluctuation of annual precipitation over the same period. $Q_a(y)$ is the monthly mean of water use in (MCM) in a year *y*, population(y) in thousand in a year *y*, income(y) in Jordan Dinar (JD) in a year *y*, precipitation(y) in (mm) in a year *y* and η are model parameters to be estimated by regression analysis using a Statistical Package for the Social Sciences (SPSS).

Table (3.3) Population, annual Income & Precipitation for the period (1990 – 2005)

Year	Population *(thousand)	Avg. annual Income (JD)**	Annual Precipitation*** (mm)
1990	231.32	476.90	286.05
1991	246.86	508.31	665.10
1992	256.4	539.72	691.65
1993	266.33	571.13	239.65
1994	276.1	602.54	647.9
1995	284.4	633.95	175.05
1996	292.3	665.36	394.15
1997	300.5	696.77	515.35
1998	308.4	728.18	252.50
1999	316.0	759.59	190.50
2000	325.4	791.00	461.15
2001	333.5	822.41	321.85
2002	341.6	853.82	587.65
2003	350.4	885.23	499.05
2004	356.0	916.64	369.70
2005	367.2	948.05	425.15

(*,**Yearly Reports of Department of Statistics for the period 1990-2005,***Department Of Meteorological, 2011)

Because the three independent variables are expected to affect on the dependent variable for the water use of trend model, multiple regression must be used by using statistical package as SPSS based on 16 years of historical observation to estimate the unknown model parameters $\eta=(\eta_0, \eta_1, \eta_2, \eta_3)$, the results of regression are shown in table (3.4).

Table (3.4) Regression Coefficients

Coefficients	**Value**
η_0	-4.4925
η_1	0.0525
η_2	-0.0137
η_3	-0.0003

Once this model parameters are estimated as shown in table (3.4), they can be used in equation (3.1), to estimate the average monthly water use $Q_a(y)$ in (MCM) for the period (1990-2005) as shown in table (3.5), notice that Q_a*'s* estimated are not closest to $Q_a(y)$ *measured*, so the reason for that it will be another factor or parameters effecting the annual average monthly of municipal water use.

Table (3.5) Average Monthly Water Use

Year	$Q_a(y)$ MCM	year	$Q_a(y)$ MCM
1990	1.03	1998	1.65
1991	1.3	1999	1.63
1992	1.37	2000	1.62
1993	1.59	2001	1.65
1994	1.55	2002	1.57
1995	1.7	2003	1.63
1996	1.62	2004	1.53
1997	1.58	2005	1.67

Using equation (3.2) in determining the annual water consumption trend is exceptionally virtual for predicting water consumption related to model parameters the $Q_b(m,y)$ can be estimate as

$$Q_b(m,y) = Q_a(m,y) - Q_a(y) \qquad (3.2)$$

where y =1990,1991,…,2005, and $Q_a(y)$ is the annual water use trend expressed by removing trend found in historical monthly water use time series $Q_a(m,y)$, then the detrended monthly water use time series $Q_b(m,y)$

can be obtained as shown in table (3.6) by using monthly average of water use $Q_a(m,y)$ in table (3.1) and the estimated average of monthly water use in table (3.5).

Table (3.6) Detrended Monthly Water use $Q_b(m,y)$ MCM

Year	Months	$Q_b(m,y)$	Year	Months	$Q_b(m,y)$
1990	1	-0.062		43	0.53
	2	-0.288		44	0.6
	3	-0.159		45	0.4225
	4	-0.052		46	-0.064
	5	0.003		47	-0.299
	6	0.26625		48	-0.123
	7	0.33625	1994	49	0.154
	8	0.4525		50	0.151
	9	0.4275		51	0.158
	10	0.113		52	0.123
	11	0.102		53	0.311
	12	0.163		54	0.67625
1991	13	-0.283		55	0.675
	14	-0.434		56	0.74625
	15	-0.284		57	0.59875
	16	-0.258		58	0.098
	17	-0.088		59	-0.117
	18	0.1875		60	0.03
	19	0.18625	1995	61	-0.033
	20	0.16375		62	-0.194
	21	0.11375		63	0.058
	22	-0.16		64	0.021
	23	-0.139		65	0.188
	24	-0.293		66	0.4925
1992	25	-0.5		67	0.61625
	26	-0.456		68	0.53125
	27	-0.282		69	0.32375
	28	-0.15		70	0.031
	29	-0.11		71	-0.112
	30	0.38		72	-0.134
	31	0.33	1996	73	-0.248
	32	0.405		74	-0.269
	33	0.53		75	-0.207
	34	0.19		76	-0.12
	35	0.15		77	0.094
	36	0.04		78	0.52625
1993	37	0.076		79	0.69875
	38	0.068		80	0.66375
	39	0.056		81	0.54625
	40	0.002		82	0.059
	41	0.207		83	-0.061
	42	0.525		84	-0.168

follow

Year	Months	$Q_b(m,y)$	Year	Months	$Q_b(m,y)$
1997	85	-0.221	2001	133	-0.546
	86	-0.34		134	-0.669
	87	-0.22		135	-0.376
	88	-0.024		136	-0.399
	89	0.116		137	-0.243
	90	0.62875		138	0.0825
	91	0.725		139	0.1475
	92	0.6725		140	0.21875
	93	0.59375		141	0.0525
	94	0.064		142	-0.328
	95	-0.111		143	-0.4833
	96	-0.189		144	-0.594
1998	97	-0.301	2002	145	-0.489
	98	-0.425		146	-0.503
	99	-0.303		147	-0.286
	100	-0.084		148	-0.139
	101	0.184		149	0.06
	102	0.775		150	0.59625
	103	0.85875		151	0.755
	104	0.5275		152	0.7925
	105	0.3025		153	0.7075
	106	-0.096		154	0.148
	107	-0.125		155	-0.083
	108	-0.152		156	-0.236
1999	109	-0.225	2003	157	-0.382
	110	-0.392		158	-0.624
	111	-0.277		159	-0.415
	112	-0.159		160	-0.313
	113	-0.013		161	0.093
	114	0.34125		162	0.59
	115	0.39		163	0.69375
	116	0.435		164	0.65
	117	0.38125		165	0.45125
	118	-0.098		166	0.013
	119	-0.199		167	-0.094
	120	-0.211		168	-0.343
2000	121	-0.477	2004	169	-0.28
	122	-0.515		170	-0.304
	123	-0.505		171	-0.052
	124	-0.246		172	0.039
	125	-0.08		173	0.338
	126	0.24625		174	0.785
	127	0.29375		175	1.02
	128	0.555		176	0.97875
	129	0.34		177	0.8175
	130	-0.317		178	0.328
	131	-0.375		179	0.133

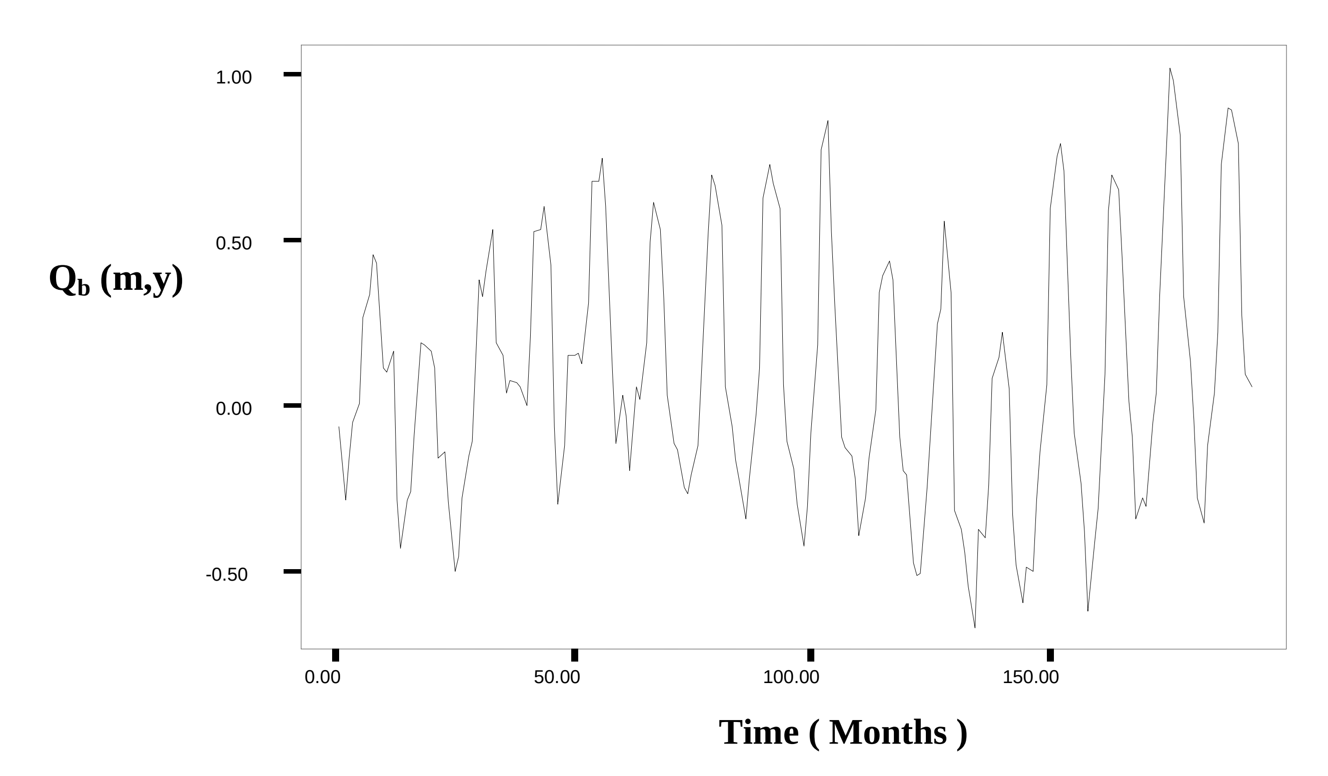
	132	-0.442		180	-0.043

Table- Continue

Year	Months	$Q_b(m,y)$	Year	Months	$Q_b(m,y)$
2005	181	-0.279		187	0.9
	182	-0.357		188	0.895
	183	-0.121		189	0.79
	184	0.038		190	0.27
	185	0.22		191	0.095
	186	0.7275		192	0.056

As shown in fig.(3.3) the detrended monthly water use time series $Q_b(m,y)$ for the period (1990-2005), the proportion of dispersion will be reduced for the monthly water use after removing the detrended from the original data $Q_a(m,y)$ using equation (3.2), Final results using SPSS shows that the detrended monthly water use time series $Q_b(m,y)$ has mean of (0.085), and standard deviation of (0.385), it is found that the standard deviation score is a widely used measure of variability or diversity from the mean value, so in this case the S.D is less than 0.42 which is related to $Q_a(m,y)$, and that's mean reduce the dispersion.

Figure (3.3) Detrended monthly water use time series $Q_b(m,y)$



3.3.2 Deseasonalization

The deseasonalization is the second stage for analyzing the historical long term components. The detrended monthly water use time series $Q_b(m,y)$ contains a seasonal water use pattern and it should be removed. Identifying that within the year of monthly seasonal water use in the detrended monthly water use time series $Q_b(m,y)$ can be used to calculate the arithmetic mean $Q_b(y)$ for each month within a year that has a seasonality using equation (3.3)

$$Q_b(m) = \frac{1}{Y}\sum_{y=1}^{Y} Q_b(m,y) \qquad (3.3)$$

Where m = 1,2 ,…, 12 and $Q_b(m,y)$ is the detrended monthly water use time series and $Q_b(m)$ the arithmetic mean.

Since the seasonality is assessed and could be happened in the monthly water use time series, so it can be modeled as periodicity by using a Fourier series to determine the within year a monthly seasonal water use pattern as shown in equation (3.4). (Mays & Tung, 1992).

$$Q_b(m) = \sum_{k=0}^{6}\left[a_k \cos\left(\frac{2\pi km}{12}\right) + b_k \sin\left(\frac{2\pi km}{12}\right)\right] \qquad (3.4)$$

Where m = 1,2…..12 the Fourier coefficients a_0, a_k and b_k can be determined using equations as follow. (Mays & Tung, 1992). In general, it is formal first six harmonics of periodic parameter sufficient and can be tested for significance. All harmonics beyond the sixth harmonic provide, relatively, only a small additional explanation of the variance of estimated value. (Mutreja, 1986).

$$a_0 = \frac{1}{12}\sum_{m=1}^{12}\left[\frac{1}{Y}\sum_{y=1}^{Y} Q_b(m,y)\right] \qquad (3.5a)$$

where Y is the number of years = 16

$$a_k = \frac{1}{6}\sum_{m=1}^{12}\left[\frac{1}{Y}\sum_{y=1}^{Y} Q_b(m,y)\right]\cos\left(\frac{2\pi km}{12}\right) \qquad (3.5b)$$

for k = 1,2…..6

$$b_k = \frac{1}{6}\sum_{m=1}^{12}\left[\frac{1}{Y}\sum_{y=1}^{Y} Q_b(m,y)\right]\sin\left(\frac{2\pi km}{12}\right) \qquad (3.5c)$$

for k = 1,2…..6, And $b_0 = 0$

Calculated the Fourier coefficients are not necessarily for all statistical significant, but only to pass the appropriate significant test used. The seasonality of water use represented by $Q_b(y)$ is removed from the

detrended water use time series $Q_b(m,y)$, so it will result in deseasonalized water use series $Q_c(m,y)$ as shown in equation (3.6). (Mays & Tung, 1992).

$$Q_c(m,y) = Q_b(m,y) - Q_b(m) \quad (3.6)$$

Where m=1,2,…,12; y =1,2,…,Y and $Q_b(y)$ is found using equation (3.4). To remove the seasonality found in detrended monthly water use which is shown in fig.(3.3), the periodicity can be identified by convenient detrended monthly water use time series to a fourier series using the average water use for each month of the detrended data, where the average of water use $Q_b(m)$ in MCM and can be computed by equation (3.3) for each month, using the detrended monthly time series $Q_b(m,y)$ in table (3.6).Then the average of water use $Q_b(m)$ in MCM can be shown in table (3.7).

Table (3.7) Average monthly water use $Q_b(m)$ in MCM

Months	$Q_b(m,y)$ MCM	Months	$Q_b(m,y)$ MCM
$Q_b(m=1)$	-0.256	$Q_b(m=7)$	0.5722656
$Q_b(m=2)$	-0.346938	$Q_b(m=8)$	0.5804688
$Q_b(m=3)$	-0.200938	$Q_b(m=9)$	0.4624219
$Q_b(m=4)$	-0.107563	$Q_b(m=10)$	0.0156875
$Q_b(m=5)$	0.08	$Q_b(m=11)$	-0.107394
$Q_b(m=6)$	0.4891406	$Q_b(m=12)$	-0.164938

The $Q_b(m)$ computed by using equation (3.3), and the Fourier coefficients are computed too but using equations (3.5*a*-*c*), and the results for those coefficients shown in table (3.8).

Table (3.8) Fourier Coefficients

a_k	Value	b_k	Value
a_0	0.084685	b_0	0
a_1	-0.32183	b_1	-0.31676
a_2	0.022804	b_2	0.095057
a_3	0.024779	b_3	0.003316
a_4	0.063289	b_4	0.003062
a_5	-0.02762	b_5	-0.01071
a_6	-0.01166	b_6	-0.00037

As shown in table (3.8) the Fourier coefficients and the average of water use $Q_b(m)$ in (MCM) as shown in table (3.7) can be used by the equation (3.4) to find the average monthly water use $Q_b(m)$ after regenerated it, so the model regenerated the values of $Q_b(m)$ as shown in table (3.9).

Table (3.9) Model Regenerated Values $Q_b(m)$ (MCM)

Months	$Q_b(m,y)$	Months	$Q_b(m,y)$
$Q_b(m=1)$	-0.41867	$Q_b(m=7)$	0.412176
$Q_b(m=2)$	-0.51967	$Q_b(m=8)$	0.408915
Qb(m=3)	-0.19454	$Q_b(m=9)$	0.468398
$Q_b(m=4)$	0.049132	$Q_b(m=10)$	0.181687
$Q_b(m=5)$	0.249426	$Q_b(m=11)$	0.062048
$Q_b(m=6)$	0.4835	$Q_b(m=12)$	-0.16383

Then the deseasonalization monthly water use time series $Q_c(m,y)$ is obtained by using equation (3.6), since the seasonality of long term trend removes the consistency of month and year deseasonalization in monthly water use time series $Q_c(m,y)$ can be changed to be $Q_c(t)$, where $t = 1,2,\ldots,192$ for deseasonalized water use time series, and it will be shown in table (3.10).

Table (3.10) Deseasonalized monthly water use time series $Q_c(t)$ MCM

Year	Months	$Q_c(m,y)$	Year	Months	$Q_c(m,y)$
1990	1	0.3566657		16	-0.307132
	2	0.2316682		17	-0.337426
	3	0.0355446		18	-0.296
	4	-0.101132		19	-0.225926
	5	-0.246426		20	-0.245165
	6	-0.21725		21	-0.354648
	7	-0.075926		22	-0.341687
	8	0.0435849		23	-0.201048
	9	-0.040898		24	-0.129169
	10	-0.068687	1992	25	-0.081334
	11	0.0399519		26	0.0636682
	12	0.326831		27	-0.087455
1991	13	0.1356657		28	-0.199132
	14	0.0856682		29	-0.359426
	15	-0.089455		30	-0.1035

Follow

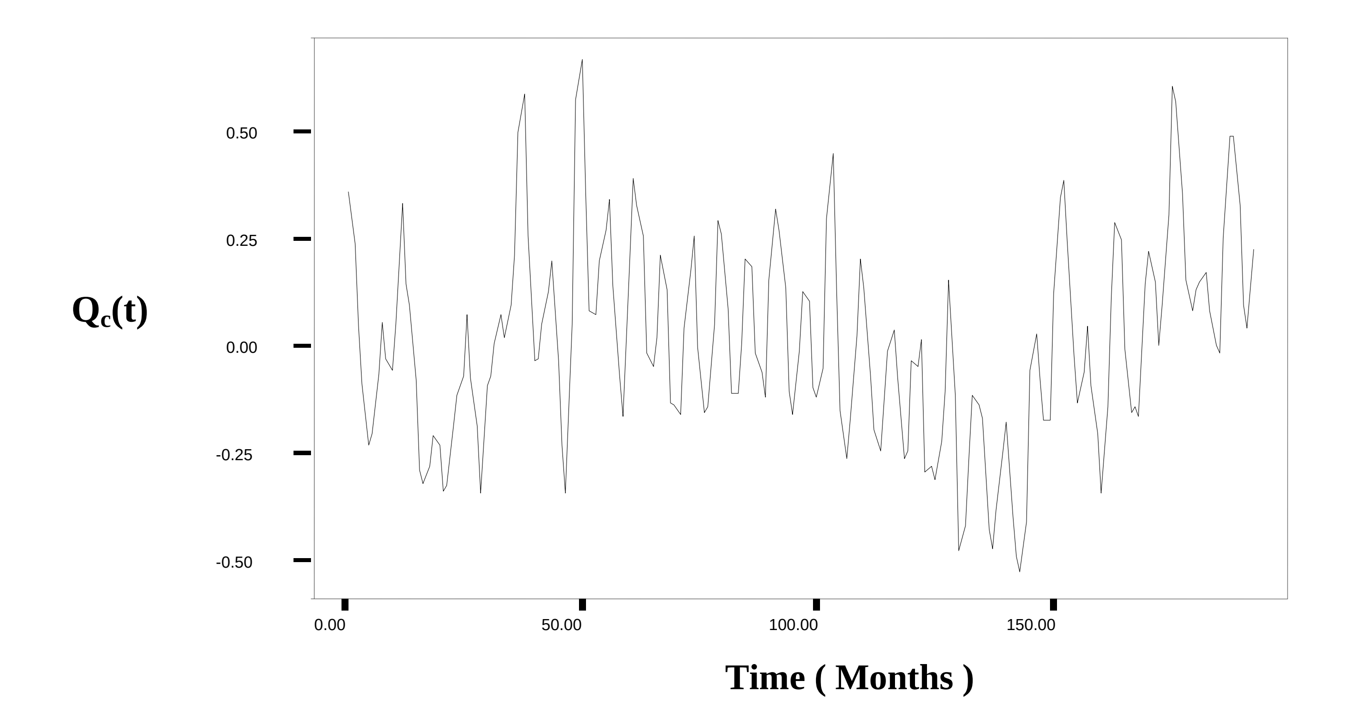
Year	Months	$Q_c(m,y)$	Year	Months	$Q_c(m,y)$
	31	-0.082176		77	-0.155426
	32	-0.003915		78	0.04275
	33	0.061602		79	0.2865743
	34	0.0083132		80	0.2548349
	35	0.0879519		81	0.077852
	36	0.203831		82	-0.122687
1993	37	0.4946657		83	-0.123048
	38	0.5876682		84	-0.004169
	39	0.2505446	1997	85	0.1976657
	40	-0.047132		86	0.1796682
	41	-0.042426		87	-0.025455
	42	0.0415		88	-0.073132
	43	0.1178243		89	-0.133426
	44	0.1910849		90	0.14525
	45	-0.045898		91	0.3128243
	46	-0.245687		92	0.2635849
	47	-0.361048		93	0.125352
1994	48	0.040831		94	-0.117687
	49	0.5726657		95	-0.173048
	50	0.6706682		96	-0.025169
	51	0.3525446	1998	97	0.1176657
	52	0.0738684		98	0.0946682
	53	0.061574		99	-0.108455
	54	0.19275		100	-0.133132
	55	0.2628243		101	-0.065426
	56	0.3373349		102	0.2915
	57	0.130352		103	0.4465743
	58	-0.083687		104	0.1185849
	59	-0.179048		105	-0.165898
	60	0.193831		106	-0.277687
1995	61	0.3856657		107	-0.187048
	62	0.3256682		108	0.011831
	63	0.2525446	1999	109	0.1936657
	64	-0.028132		110	0.1276682
	65	-0.061426		111	-0.082455
	66	0.009		112	-0.208132
	67	0.2040743		113	-0.262426
	68	0.1223349		114	-0.14225
	69	-0.144648		115	-0.022176
	70	-0.150687		116	0.0260849
	71	-0.174048		117	-0.087148
	72	0.029831		118	-0.279687
1996	73	0.1706657		119	-0.261048
	74	0.2506682		120	-0.047169
	75	-0.012455	2000	121	-0.058334
	76	-0.169132		122	0.0046682

follow

Year	Months	$Q_c(m,y)$	Year	Months	$Q_c(m,y)$
	123	-0.310455		158	-0.104332
	124	-0.295132		159	-0.220455
	125	-0.329426		160	-0.362132
	126	-0.23725		161	-0.156426
	127	-0.118426		162	0.1065
	128	0.1460849		163	0.2815743
	129	-0.128398		164	0.2410849
	130	-0.498687		165	-0.017148
	131	-0.437048		166	-0.168687
	132	-0.278169		167	-0.156048
2001	133	-0.127334		168	-0.179169
	134	-0.149332	2004	169	0.1386657
	135	-0.181455		170	0.2156682
	136	-0.448132		171	0.1425446
	137	-0.492426		172	-0.010132
	138	-0.401		173	0.088574
	139	-0.264676		174	0.3015
	140	-0.190165		175	0.6078243
	141	-0.415898		176	0.5698349
	142	-0.509687		177	0.349102
	143	-0.545348		178	0.1463132
	144	-0.430169		179	0.0709519
2002	145	-0.070334	2005	180	0.120831
	146	0.0166682		181	0.1396657
	147	-0.091455		182	0.1626682
	148	-0.188132		183	0.0735446
	149	-0.189426		184	-0.011132
	150	0.11275		185	-0.029426
	151	0.3428243		186	0.244
	152	0.3835849		187	0.4878243
	153	0.239102		188	0.4860849
	154	-0.033687		189	0.321602
	155	-0.145048		190	0.0883132
	156	-0.072169		191	0.0329519
2003	157	0.0366657		192	0.219831

The deseasonalization monthly water use time series $Q_c(t)$ for the period (1990-2005), are shown in fig.(3.4). The proportion of dispersion will be reduced for the monthly water use after removing the seasonality from the detrended monthly water use time series $Q_b(m,y)$ using equation (3.6). Final results using SPSS shows that the deseasonalization monthly water use time series $Q_c(t)$ has mean of (-0.0002), and standard deviation of (0.238), which is less than S.D of detrended (0.385), so this stage has reduced the rate of dispersion.

Figure (3.4) Deseasonalization monthly water use time series $Q_c(t)$



3.3.3 Autoregressive Filtering

The third stage in developing cascade model is to use autoregressive filtering analysis, to identify the short term memory components in $Q_c(t)$. The detrended and deseasonalization of monthly water use time series $Q_c(m,y)$ now does not possess over-year trend and within-year seasonality, and can be represented as $Q_c(m,y)$. Still the detrended and deseasonalization may possess, like many hydrologic time series, so the equation (3.7) can be obtained $Q_c(t)$ as

$$Q_c(t) = \sum_{i=1}^{I} \Phi_i Q_c(t-i) + Q_d(t) \qquad (3.7)$$

Where $t = 2,\dots, T$, and $Q_c(t-i)$ is the detrended and deseasonalization of monthly water use time series lagged by i months; I total No. of lag's, Φ*'s* are the unknown autoregressive coefficients and $Q_d(t)$ is the residual representing the water use time series after autoregressive has been removed. Within $Q_c(t)$. The autoregressive coefficients Φ_i and $Q_d(t)$ can be estimated using a linear regression analysis in statistical package SPSS of the equation (3.8).

$$Q_c(t) = \Phi_0 + \Phi_1 Q_c(t-1) \qquad (3.8)$$

Where t = 2,3,…..,192 and $Q_c(t) = Q_c(m,y)$, and the residential $Q_d(t)$ represents the water use time series after autoregressive has been removed using equation (3.7), Thus the autoregressive coefficients Φ_i are Φ_0 = -0.002 , Φ_1 = 0.741.

Autocorrelation founded in time series is measure of persistence of the observation the existence of which can be identified by computing the autocorrelation coefficients of the different time lags, so the autocorrelation founded in deseasonalized water use time series can be used only lag-1atutocorrelation.

The residual $Q_d(t)$ are founded using equation (3.7) as given in table (3.11). Note that the first value of $Q_d(1) = zero$, assumed that since t starts for t = 2 in this autoregressive of t , say $Q_d(t) = Q_c(t)$(measured) – $Q_c(t)$ (modeled) and given by $Q_c(t) = Q_c(1) + \ldots\ldots.. + Q_c(192)$ for t = 1 , assume no difference between measured and modeled then the first value of $Q_d(1) = zero$ the following equation represent $Q_d(t)$ as

$$Q_d(t) = Q_c(t) - (-0.002 + 0.741*Q_c(t-1)) \ldots \text{ where } t = 2,3,\ldots,192.$$

Table (3.11) Autoregressive monthly water use time series $Q_d(t)$ MCM

Year	Months	$Q_d(m,y)$	Year	Months	$Q_d(m,y)$
1990	1	0		21	-0.170981
	2	-0.030621		22	-0.076893
	3	-0.134122		23	0.0541418
	4	-0.12547		24	0.0218076
	5	-0.169487	1992	25	0.0163799
	6	-0.032648		26	0.1259369
	7	0.0870565		27	-0.132634
	8	0.1018459		28	-0.132327
	9	-0.071194		29	-0.209869
	10	-0.036381		30	0.1648346
	11	0.0928488		31	-0.003482
	12	0.2992266		32	0.0589771
1991	13	-0.104516		33	0.0665031
	14	-0.01286		34	-0.035334
	15	-0.150936		35	0.0837918
	16	-0.238845		36	0.1406586
	17	-0.107841	1993	37	0.3456269
	18	-0.043967		38	0.2231209
	19	-0.00459		39	-0.182918
	20	-0.075754		40	-0.230785

follow

Year	Months	$Q_d(m,y)$	Year	Months	$Q_d(m,y)$
	41	-0.005501		81	-0.108981
	42	0.0749376		82	-0.178375
	43	0.0890728		83	-0.030137
	44	0.1057771		84	0.0890096
	45	-0.185492	1997	85	0.2027549
	46	-0.209676		86	0.0351979
	47	-0.176994		87	-0.15659
	48	0.3103676		88	-0.052269
1994	49	0.5444099		89	-0.077235
	50	0.2483229		90	0.2461186
	51	-0.142421		91	0.207194
	52	-0.185367		92	0.0337821
	53	0.0088375		93	-0.067964
	54	0.1491236		94	-0.208573
	55	0.1219965		95	-0.083842
	56	0.1445821		96	0.1050596
	57	-0.117613	1998	97	0.1383159
	58	-0.178278		98	0.0094779
	59	-0.115036		99	-0.176605
	60	0.3285056		100	-0.050766
1995	61	0.2440369		101	0.0352245
	62	0.0418899		102	0.3419806
	63	0.0132245		103	0.2325728
	64	-0.213267		104	-0.210327
	65	-0.03858		105	-0.251769
	66	0.0565166		106	-0.152756
	67	0.1994053		107	0.0207178
	68	-0.026884		108	0.1524336
	69	-0.233298	1999	109	0.1868989
	70	-0.041503		110	-0.013838
	71	-0.060389		111	-0.175058
	72	0.1608006		112	-0.145032
1996	73	0.1505609		113	-0.1062
	74	0.1262049		114	0.0542076
	75	-0.196201		115	0.0852315
	76	-0.157902		116	0.0445171
	77	-0.028099		117	-0.104477
	78	0.1599206		118	-0.21311
	79	0.2568965		119	-0.0518
	80	0.0444834		120	0.1482676

follow

Year	Months	$Q_d(m,y)$	Year	Months	$Q_d(m,y)$
2000	121	-0.021382	2003	157	0.0921429
	122	0.0498939		158	-0.129501
	123	-0.311915		159	-0.141146
	124	-0.063084		160	-0.196774
	125	-0.108733		161	0.1139135
	126	0.0088546		162	0.2244116
	127	0.0593765		163	0.2046578
	128	0.2358384		164	0.0344384
	129	-0.234647		165	-0.193792
	130	-0.401544		166	-0.15398
	131	-0.065521		167	-0.029051
	132	0.0476836		168	-0.061537
2001	133	0.0807889	2004	169	0.2734299
	134	-0.052977		170	0.1149169
	135	-0.068801		171	-0.015266
	136	-0.311673		172	-0.113757
	137	-0.15836		173	0.0980815
	138	-0.034112		174	0.2378666
	139	0.0344653		175	0.3864128
	140	0.0079596		176	0.1214371
	141	-0.272986		177	-0.071146
	142	-0.199506		178	-0.110371
	143	-0.16567		179	-0.035466
	144	-0.024066		180	0.0702556
2002	145	0.2504209	2005	181	0.0521299
	146	0.0707859		182	0.0611759
	147	-0.101807		183	-0.044993
	148	-0.118363		184	-0.063628
	149	-0.04802		185	-0.019177
	150	0.2551146		186	0.2678046
	151	0.2612765		187	0.3090203
	152	0.1315521		188	0.1266071
	153	-0.043134		189	-0.036587
	154	-0.208861		190	-0.147994
	155	-0.118086		191	-0.030488
	156	0.0373116		192	0.1974136

As shown in fig.(3.5) the autoregressive monthly water use time series $Q_d(t)$ for the period (1990-2005), the proportion of dispersion will be reduced for the monthly water use after removing the autocorrelation from the deseasonalized monthly water use time series $Q_c(m,y)$ using equation (3.7). Final results using SPSS shows that the autoregressive monthly water use time series $Q_d(t)$ has mean of (1.49), and S.D (0.158) which less that S.D(0.238)in deseasonalized, so this stage has reduced rates of dispersion.

Figure (3.5) Autoregressive monthly water use time series $Q_d(t)$

0.50
0.25
$Q_d(t)$
0.00
-0.25
0.00 50.00 100.00 150.00
Time (Months)

3.3.4 Climatic Regression

The final step in cascade model development is to compute the monthly water use time series $Q_d(t)$ which is represent the dependent variable depending on two climatic parameters presented independent variables as monthly precipitation and monthly average temperature for the period (1990-2005) shown in equation (3.9) as

$$Q_d(t) = \sum_{l=1}^{L} \beta_l \, x_l(t) + Q_e(t) \qquad (3.9)$$

where $t = 1,2, \ldots\ldots, T$ and X_l is the lth climatic factor, L is the total number of climatic factors and $Q_e(t)$ is the residuals that gives the equation a clear correlation without errors to be balanced in each of direction that zero mean with constant variance. The unknown model coefficients β*'s* in equation (3.9) can be estimated using a linear regression

analysis by using the historical data for the climatic variables as shown in table (3.6) and the dependent variable $Q_d(t)$ which are known values, and the regression equation as

$$Q_d(t)=\beta_0+\beta_1*\text{monthly precip.}+\beta_2*\text{max. monthly average temp.} + Q_e(t) \quad (3.9)$$

Where unknown model coefficients *β's* are estimated using linear regression , the monthly precipitation in (mm) and the monthly average temperature in (C□).

Table (3.12) shows the monthly precipitation (mm) and temperature (C□) from January to December over the period (1990-2005), notice that the monthly precipitation (mm) is zero summer months, and the highest value of monthly precipitation (mm) is at the beginning and end of each year due to winter season, and notice that the monthly temperature (C□) during June to October over the same period is higher than the other months, due to summer season, and the lowest value of monthly temperature (C□) is at the beginning and end of each year due to winter season.

Table (3.12) Monthly Total Precipitation & Monthly Average Temperature for the period (1990-2005) (Department of metrological, 2011)

Year	Months	Precipitation (mm)	Temperature (C□)
1990	1	104.35	13.65
	2	50.9	15.4
	3	64	19.45
	4	30.2	24.25
	5	0	29.15
	6	0	32.1
	7	0	33.75
	8	0	34
	9	0	31.4
	10	6	29.8
	11	30.2	24.55
	12	0.4	19.6
1991	13	129.25	15
	14	47.15	16.6
	15	118.75	20.05
	16	20.65	25.65
	17	1.15	29.15
	18	0	32.5

Follow

Year	Months	Precipitation (mm)	Temperature (C□)
	19	0	33.3
	20	0	33.3
	21	0	32.05
	22	11.5	29.35
	23	90.15	23
	24	246.5	14.2
1992	25	128.35	10.9
	26	291.9	11
	27	44	16.35
	28	1.9	23
	29	7.2	27.6
	30	2.55	31.35
	31	0	32.5
	32	0	34
	33	0	31.45
	34	0	30.35
	35	55.2	21.8
	36	160.55	13.15
1993	37	91.15	13.45
	38	71.05	13.15
	39	24.35	18.45
	40	0	25.45
	41	14.2	27.25
	42	0	33.05
	43	0	33.45
	44	0	34.6
	45	0.05	32.15
	46	6.05	30.55
	47	13.15	21.55
	48	19.65	19.8
1994	49	144.3	16.3
	50	66	15.85
	51	59.25	18.8
	52	4.8	27.75
	53	0.15	30.65
	54	1.05	31.75
	55	0	33.1
	56	0	34.1

follow

Year	Months	Precipitation (mm)	Temperature (C□)
	57	2.9	33.8
	58	38.65	30.7
	59	206.2	18.8
	60	124.6	13.85
1995	61	18.5	15.7
	62	69.2	16.65
	63	21.4	20.1
	64	11.7	23.75
	65	0.85	30.25
	66	0	33.35
	67	0	33.3
	68	0	34.05
	69	0	32.8
	70	1	27.95
	71	22.1	20.75
	72	30.3	16.5
1996	73	140.55	14.9
	74	21.3	17.4
	75	130.05	17.8
	76	11.75	23.5
	77	0	31.2
	78	0	32.55
	79	0	34.8
	80	0	34.6
	81	0	32.85
	82	20.35	27.25
	83	9.5	23.5
	84	60.65	18.55
1997	85	83.5	16.45
	86	152.95	13.75
	87	101.35	16.05
	88	5.85	22.25
	89	8.8	30.95
	90	0	32.6
	91	0	34
	92	0	32.2
	93	1.75	31.1
	94	13.1	28.9
	95	49.95	22.45

follow

Year	Months	Precipitation (mm)	Temperature (C□)
	96	98.1	17.1
1998	97	102.85	14.15
	98	45.4	16.25
	99	86.95	17.45
	100	4.35	26.1
	101	1.1	30.2
	102	0	32.7
	103	0	35
	104	0	36.1
	105	0.05	33.35
	106	0.7	30.35
	107	1	25.85
	108	10.1	19.2
1999	109	79.95	17.05
	110	47.7	17.9
	111	33.3	20.9
	112	9.15	25.25
	113	0	31.6
	114	0	32.1
	115	0	34.25
	116	0	35.1
	117	0	32.65
	118	3.35	28.85
	119	3.5	23.65
	120	13.55	19.6
2000	121	173.25	13.6
	122	74.15	15.55
	123	63.05	18.1
	124	1.4	26.05
	125	0	29.45
	126	0	33.3
	127	0.05	36.95
	128	0	34.15
	129	0.35	32.1
	130	27.35	27
	131	4.75	23.5
	132	116.8	16.85
2001	133	68.5	16.8
	134	52.55	16.25

follow

Year	Months	Precipitation (mm)	Temperature (C□)
	135	7.1	25.35
	136	8.5	27.05
	137	22.8	30
	138	0	34.2
	139	0	35.1
	140	0	34.75
	141	0	32.15
	142	7.85	29.05
	143	56.4	22.05
	144	98.15	17.05
2002	145	185.7	13.35
	146	49.45	19.1
	147	78.7	22.5
	148	32.7	23.25
	149	1.25	30
	150	0	32.65
	151	0	35.6
	152	0	34.3
	153	0	33.55
	154	16	30.4
	155	28.9	23.85
	156	194.95	16.25
2003	157	55.6	16.9
	158	201.3	14.05
	159	136.3	16.7
	160	19.65	24.45
	161	0	33.1
	162	0	32.75
	163	0	34.35
	164	0	35.15
	165	0	31.95
	166	0	29.8
	167	16.6	23.85
	168	69.6	16.75
2004	169	124.15	15.15
	170	45.95	16.75
	171	24.9	22.7
	172	0.25	25.95
	173	1.25	29.25
	174	0	32.3

Follow

Year	Months	Precipitation (mm)	Temperature (C□)
2005	175	0	35.4
	176	0	33.7
	177	0	33.4
	178	6.05	30.75
	179	135.1	22.45
	180	32.05	15.85
	181	125.9	15.45
	182	99.25	15.2
	183	29.15	20.95
	184	8.75	25.95
	185	4.5	28.75
	186	0	32.25
	187	0	34.75
	188	0	34.75
	189	0	32.6
	190	2.1	28.3
	191	37.35	22.15
	192	118.15	19.8

Table (3.13) shows the results of unknown model parameters by multi-linear regression analysis, the two independent variables are expected to affect on the dependent variable for the monthly water use time series $Q_d(t)$, based on 16 years of historical observation to estimate the unknown model parameters $\beta=(\beta_0, \beta_1, \beta_2)$, the results shows the relationship between independent variables and dependent variable

Table (3.13) Regression Coefficients

Coefficients	value
β_0	-0.054
β_1	0.0005
β_2	0.0015

The residual time series $Q_e(t)$ from climatic regression is shown in table (3.14) as follow:

Table (3.14) The residual Time Series $Q_e(t)$

Year	Months	$Q_e(m,y)$	Year	Months	$Q_e(m,y)$
1990	1	0.01865	1993	37	0.01175
	2	-0.00545		38	0.00125
	3	0.007175		39	-0.01415
	4	-0.002525		40	-0.015825
	5	-0.010275		41	-0.006025
	6	-0.00585		42	-0.004425
	7	-0.003375		43	-0.003825
	8	-0.003		44	-0.0021
	9	-0.0069		45	-0.00575
	10	-0.0063		46	-0.00515
	11	-0.002075		47	-0.0151
	12	-0.0244		48	-0.014475
1991	13	0.033125	1994	49	0.0426
	14	-0.005525		50	0.002775
	15	0.03545		51	0.003825
	16	-0.0052		52	-0.009975
	17	-0.0097		53	-0.00795
	18	-0.00525		54	-0.00585
	19	-0.00405		55	-0.00435
	20	-0.00405		56	-0.00285
	21	-0.005925		57	-0.00185
	22	-0.004225		58	0.011375
	23	0.025575		59	0.0773
	24	0.09055		60	0.029075
1992	25	0.026525	1995	61	-0.0212
	26	0.10845		62	0.005575
	27	-0.007475		63	-0.01315
	28	-0.01855		64	-0.012525
	29	-0.009		65	-0.0082
	30	-0.0057		66	-0.003975
	31	-0.00525		67	-0.00405
	32	-0.003		68	-0.002925
	33	-0.006825		69	-0.0048
	34	-0.008475		70	-0.011575
	35	0.0063		71	-0.011825
	36	0.046		72	-0.0141

follow

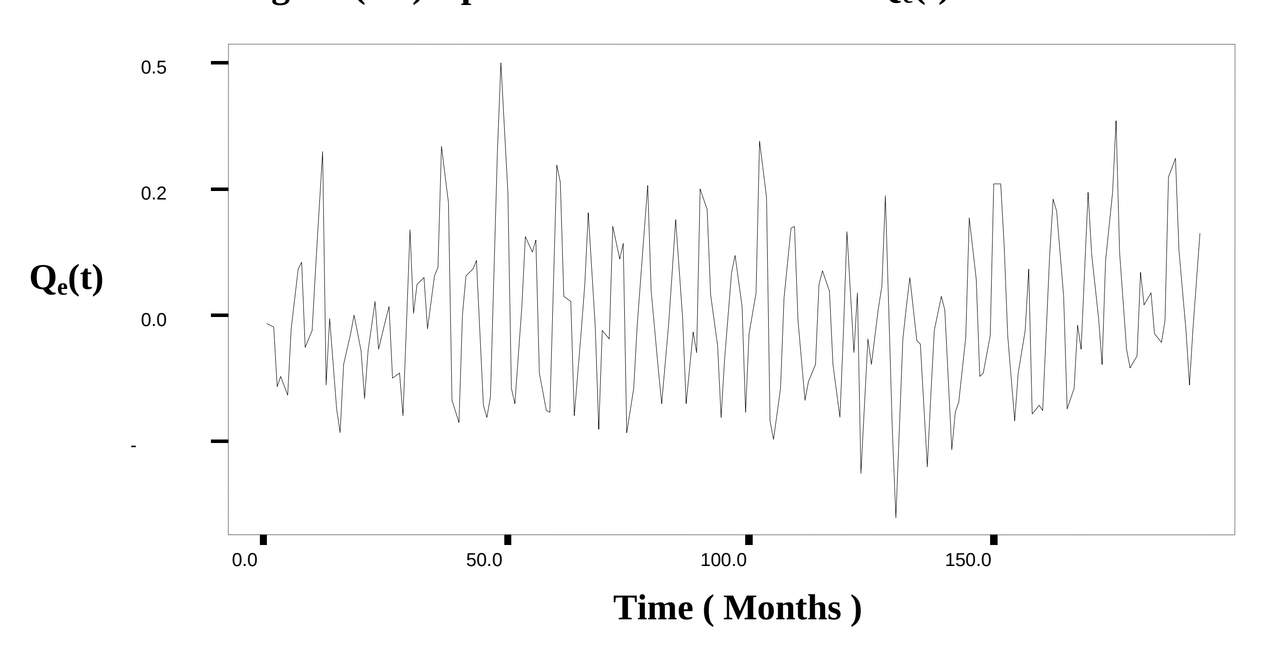
Year	Months	$Q_e(m,y)$	Year	Months	$Q_e(m,y)$
1996	73	0.038625		116	-0.00135
	74	-0.01725		117	-0.005025
	75	0.037725		118	-0.00905
	76	-0.012875		119	-0.016775
	77	-0.0072		120	-0.017825
	78	-0.005175	2000	121	0.053025
	79	-0.0018		122	0.0064
	80	-0.0021		123	0.004675
	81	-0.004725		124	-0.014225
	82	-0.00295		125	-0.009825
	83	-0.014		126	-0.00405
	84	0.00415		127	0.00145
1997	85	0.012425		128	-0.002775
	86	0.0431		129	-0.005675
	87	0.02075		130	0.000175
	88	-0.0177		131	-0.016375
	89	-0.003175		132	0.029675
	90	-0.0051	2001	133	0.00545
	91	-0.003		134	-0.00335
	92	-0.0057		135	-0.012425
	93	-0.006475		136	-0.009175
	94	-0.0041		137	0.0024
	95	0.00465		138	-0.0027
	96	0.0207		139	-0.00135
1998	97	0.01865		140	-0.001875
	98	-0.006925		141	-0.005775
	99	0.01565		142	-0.0065
	100	-0.012675		143	0.007275
	101	-0.00815		144	0.02065
	102	-0.00495	2002	145	0.058875
	103	-0.0015		146	-0.000625
	104	0.00015		147	0.0191
	105	-0.00395		148	-0.002775
	106	-0.008125		149	-0.008375
	107	-0.014725		150	-0.005025
	108	-0.02015		151	-0.0006
1999	109	0.01155		152	-0.00255
	110	-0.0033		153	-0.003675
	111	-0.006		154	-0.0004
	112	-0.01155		155	-0.003775
	113	-0.0066		156	0.06785
	114	-0.00585	2003	157	-0.00085
	115	-0.002625		158	0.067725

Follow

Year	Months	$Q_e(m,y)$	Year	Months	$Q_e(m,y)$
	159	0.0392		176	-0.00345
	160	-0.0075		177	-0.0039
	161	-0.00435		178	-0.00485
	162	-0.004875		179	0.047225
	163	-0.002475		180	-0.0142
	164	-0.001275	2005	181	0.032125
	165	-0.006075		182	0.018425
	166	-0.0093		183	-0.008
	167	-0.009925		184	-0.0107
	168	0.005925		185	-0.008625
2004	169	0.0308		186	-0.005625
	170	-0.0059		187	-0.001875
	171	-0.0075		188	-0.001875
	172	-0.01495		189	-0.0051
	173	-0.0095		190	-0.0105
	174	-0.00555		191	-0.0021
	175	-0.0009		192	0.034775

Final results using SPSS shows that the residual time series $Q_e(t)$ from climatic regression is shown in table (3.14) has mean of (0.002), and S.D (0.02) which less that S.D(0.158) in the autoregressive monthly water use time series $Q_d(t)$, so this stage has reduced rates of dispersion.which represent low dispersion is shown in figure(3.6).

Figure (3.6) Apure random error series $Q_e(t)$



3.4 Application for Forecast the Future Municipal Water Demand

To forecast the municipal future demand of water, through the process of transforming historical monthly water use data as described before, assume that the cascade model has been developed with all its unknown coefficients estimated. Then future municipal water demand can be predicted by the developed cascade model as follow:

$$Q_a(t) = Q_a(m,y) = Q_a(y) + Q_b(m) + Q_c(t) + Q_d(t) \qquad (3.11)$$

All of these predicted values with each term can be calculated by the following equations:

$$Q_a(y) = \eta_0 + \eta_1 * Population(y) + \eta_2 * Income(y) + \eta_3 * Precipitation(y)$$

$$Q_b(m) = \sum_{k=0}^{6}\left[a_k \cos\left(\frac{2\pi km}{12}\right) + b_k \sin\left(\frac{2\pi km}{12}\right)\right] \quad \ldots, \quad m = 1,2\ldots..12$$

$$Q_c(t) = \Phi_0 + \Phi_1 Q_c(t-1) \ \ldots \text{ for } t = 2,3,\ldots..,192$$

$$Q_d(t) = \beta_0 + \beta_1 * \text{monthly precip.} + \beta_2 * \text{max. monthly average temperature}$$

The future total water use is then the sum of all four components. Before predicting a future demand of water, two steps of analysis have to be used. Namely, first, accuracy of the model for the period (1990-2005), second, model verification for the period (2006-2010), as shown below, then the prediction of future water use for the period (2011-2020) can be estimated.

3.5 Accuracy of the Model for the Period (1990-2005)

After developing the cascade model from historical data using time series analysis in two successive development stages, the estimated values *(η , a_k , b_k ,Φ and β)* from the regression analysis were employed in developing the cascade model stages by using historical data for the period (1990-2005), related to population growth in thousand, annual income in (JD), annual precipitation in (mm), monthly precipitation in (mm) and monthly temperature in (C□) Therefore, the historical data related to total municipal monthly water use time series can be represented as *Q measured* in (MCM), and the estimated total municipal monthly water use can be represented as *Q modeled* in (MCM). Thus it can be compared between these two values: *Q measured* and *Q modeled*, in which the last one is estimated using time series analysis. As shown in table (3.15) there is a harmony between the values of *Q measured* and of *Q modeled* for the period (1990-2005). Table (3.15) shows *Q measured* and of *Q modeled* for the period (1990-2005). The difference between *Q measured* and *Q*

modeled was very low, with a few large differences between *Q measured* and *Q modeled* occurred somewhere.

Results are shown in table (3.16). It is very important at this stage of analysis to state that specific measures of model performance have been employed to assess quantitatively the model. These measures are statistical indicators, and these are:

1- The mean of residual error.
2- The variance of residual error.
3- The standard deviation of residual error.
4- The mean of absolute residual error.
5- The standard error of mean.
6- The root mean of squared residual error.
7- The linear regression coefficient.

Table (3.16) shows the value of the statistical indicators.

This conclusion gives the cascade model a sort of confidence in the forecast of future monthly water demand. Note that, to estimate total municipal monthly water use *Q modeled* in (MCM), it needed finding the components for the development of cascade model stages as Q_a , Q_b , Q_c and Q_d. These can then be shown in Appendix I table (I.1).

Table (3.15) Monthly water demand measured VS modeled (MCM)

Month	Q total Modeled	Q total Measured	Differences	Month	Q total Modeled	Q total Measured	Differences
1	0.63044	0.968	0.348724	21	1.58308	1.41375	0.11977
2	0.76962	0.742	0.03723	22	1.21694	1.14	0.06749
3	1.01476	0.871	0.16505	23	1.13671	1.161	0.020925
4	1.1034	0.978	0.12822	24	1.08002	1.007	0.07251
5	1.19467	1.033	0.1565	25	0.87698	0.87	0.00803
6	1.3255	1.29625	0.02257	26	0.89335	0.914	0.022591
7	1.27827	1.36625	0.064393	27	1.21	1.088	0.11214
8	1.38011	1.4825	0.069066	28	1.33062	1.22	0.09067
9	1.52425	1.4575	0.0458	29	1.45771	1.26	0.15691
10	1.17554	1.143	0.02847	30	1.57631	1.75	0.099254
11	1.03953	1.132	0.081686	31	1.69507	1.7	0.002898
12	0.87183	1.193	0.269213	32	1.70986	1.775	0.036696
13	1.15891	1.017	0.13954	33	1.82351	1.9	0.040256
14	0.87761	0.866	0.0134	34	1.5837	1.56	0.01519
15	1.20666	1.016	0.18766	35	1.43935	1.52	0.05306
16	1.27992	1.042	0.22833	36	1.31218	1.41	0.069374
17	1.31441	1.212	0.0845	37	1.33557	1.666	0.198339
18	1.53049	1.4875	0.0289	38	1.43958	1.658	0.131739
19	1.49106	1.48625	0.00324	39	1.81822	1.646	0.10463
20	1.53973	1.46375	0.05191	40	1.81041	1.592	0.13719

follow

Month	Q total Modeled	Q total Measured	Differences	Month	Q total Modeled	Q total Measured	Differences
41	1.79993	1.797	0.00163	78	1.98073	2.14625	0.077122
42	2.03909	2.115	0.035893	79	2.05963	2.31875	0.111751
43	2.03055	2.12	0.042193	80	2.23674	2.28375	0.020585
44	2.08557	2.19	0.047684	81	2.27008	2.16625	0.04793
45	2.19569	2.0125	0.09103	82	1.854	1.679	0.10423
46	1.73398	1.526	0.13629	83	1.57471	1.559	0.01008
47	1.45634	1.291	0.12807	84	1.36671	1.452	0.058737
48	1.14561	1.467	0.219082	85	1.17206	1.359	0.137556
49	1.20577	1.704	0.29239	86	1.2513	1.24	0.00911
50	1.45903	1.701	0.14225	87	1.54074	1.36	0.1329
51	1.85783	1.708	0.08772	88	1.59397	1.556	0.0244
52	1.85197	1.673	0.10698	89	1.77346	1.696	0.04567
53	1.84779	1.861	0.007096	90	1.96093	2.20875	0.1122
54	2.07486	2.22625	0.068003	91	2.0982	2.305	0.089717
55	2.10224	2.225	0.055175	92	2.21641	2.2525	0.016021
56	2.1524	2.29625	0.062646	93	2.23864	2.17375	0.02985
57	2.2681	2.14875	0.05554	94	1.85187	1.644	0.12644
58	1.84123	1.648	0.11725	95	1.56089	1.469	0.06255
59	1.62892	1.433	0.13672	96	1.31004	1.391	0.058205
60	1.28415	1.58	0.187245	97	1.22601	1.349	0.091168
61	1.40263	1.667	0.158591	98	1.20528	1.225	0.016099
62	1.47055	1.506	0.023537	99	1.53594	1.347	0.14027
63	1.7325	1.758	0.014505	100	1.60078	1.566	0.02221
64	1.92261	1.721	0.11715	101	1.78731	1.834	0.025458
65	1.91925	1.888	0.01655	102	2.07475	2.425	0.144432
66	2.13288	2.1925	0.027193	103	2.27136	2.50875	0.094624
67	2.11366	2.31625	0.087462	104	2.38466	2.1775	0.09514
68	2.25608	2.23125	0.01113	105	2.197	1.9525	0.12523
69	2.25312	2.02375	0.11334	106	1.69532	1.554	0.09094
70	1.7618	1.731	0.01779	107	1.48624	1.525	0.025416
71	1.63743	1.588	0.03113	108	1.3221	1.498	0.117422
72	1.39197	1.566	0.11113	109	1.23361	1.405	0.121983
73	1.25963	1.372	0.0819	110	1.2525	1.238	0.01172
74	1.20712	1.351	0.106502	111	1.52603	1.353	0.12789
75	1.6465	1.413	0.16525	112	1.60845	1.471	0.09344
76	1.6446	1.5	0.0964	113	1.72057	1.617	0.06405
77	1.73447	1.714	0.01194	114	1.91516	1.97125	0.028454

follow

Month	Q total Modeled	Q total Measured	Differences	Month	Q total Modeled	Q total Measured	Differences
115	1.93611	2.02	0.041529	154	1.92433	1.718	0.1201
116	2.0231	2.065	0.020291	155	1.59918	1.487	0.07544
117	2.11467	2.01125	0.05142	156	1.36241	1.334	-0.0213
118	1.74003	1.532	0.13579	157	1.15114	1.248	0.077615
119	1.46999	1.431	0.02725	158	1.19936	1.006	0.19221
120	1.25688	1.419	0.114253	159	1.39148	1.215	0.14525
121	1.21336	1.143	0.06156	160	1.50241	1.317	0.14078
122	1.05746	1.105	0.043023	161	1.60087	1.723	0.070882
123	1.42755	1.115	0.28031	162	1.98685	2.22	0.105024
124	1.41881	1.374	0.03262	163	2.11275	2.32375	0.090801
125	1.63486	1.54	0.0616	164	2.24042	2.28	0.017359
126	1.8493	1.86625	0.009082	165	2.2651	2.08125	0.08834
127	1.85178	1.91375	0.032382	166	1.78381	1.643	0.08571
128	1.93234	2.175	0.111567	167	1.55126	1.536	0.00993
129	2.18493	1.96	0.11476	168	1.3506	1.287	0.04942
130	1.70067	1.303	0.3052	169	1.00599	1.25	0.19521
131	1.2901	1.245	0.03623	170	1.1038	1.226	0.099671
132	1.15595	1.178	0.01872	171	1.48439	1.478	0.00432
133	1.03133	1.104	0.06582	172	1.66643	1.569	0.0621
134	1.0333	0.981	0.05332	173	1.75904	1.868	0.05833
135	1.33306	1.274	0.04636	174	2.07021	2.315	0.105743
136	1.55618	1.251	0.24395	175	2.16131	2.55	0.152428
137	1.57044	1.407	0.11616	176	2.38248	2.50875	0.05033
138	1.76659	1.7325	0.01968	177	2.41337	2.3475	0.02806
139	1.76436	1.7975	0.018435	178	1.96214	1.858	0.05605
140	1.86159	1.86875	0.00383	179	1.74431	1.663	0.0489
141	1.97239	1.7025	0.15852	180	1.40117	1.487	0.057722
142	1.51768	1.322	0.14802	181	1.37066	1.391	0.014622
143	1.34232	1.1667	0.15053	182	1.26992	1.313	0.032812
144	1.1034	1.056	0.04488	183	1.58567	1.549	0.02367
145	0.88732	1.081	0.179167	184	1.7606	1.708	0.0308
146	0.99346	1.067	0.068924	185	1.90022	1.89	0.00541
147	1.40278	1.284	0.09251	186	2.12374	2.3975	0.114185
148	1.54446	1.431	0.07929	187	2.25877	2.57	0.121099
149	1.66752	1.63	0.02302	188	2.43619	2.565	0.050219
150	1.90398	2.16625	0.12107	189	2.49116	2.46	0.01267
151	2.06099	2.325	0.113551	190	2.07716	1.94	0.0707
152	2.22627	2.3625	0.057664	191	1.79306	1.765	0.0159
153	2.31483	2.2775	0.01639	192	1.56303	1.726	0.094419

Table (3.16) shows the value of the statistical indicators as follow related to absolute difference:

Table (3.16) The statistical indicators of residual error

Statistics	Differences	Absolute Differences
Mean	-0.007524686	0.082039472
Std. Error of Mean	0.007484147	0.004590295
Std. Deviation	0.103703379	0.063604992
Variance	0.010754391	0.004045595
Root Mean of Squared	0.10371	0.10371

Figure (3.7) shows the linear regression between *Q modeled* and *Q measured:*

Figure (3.7) (Linear Regression) Demand MCM

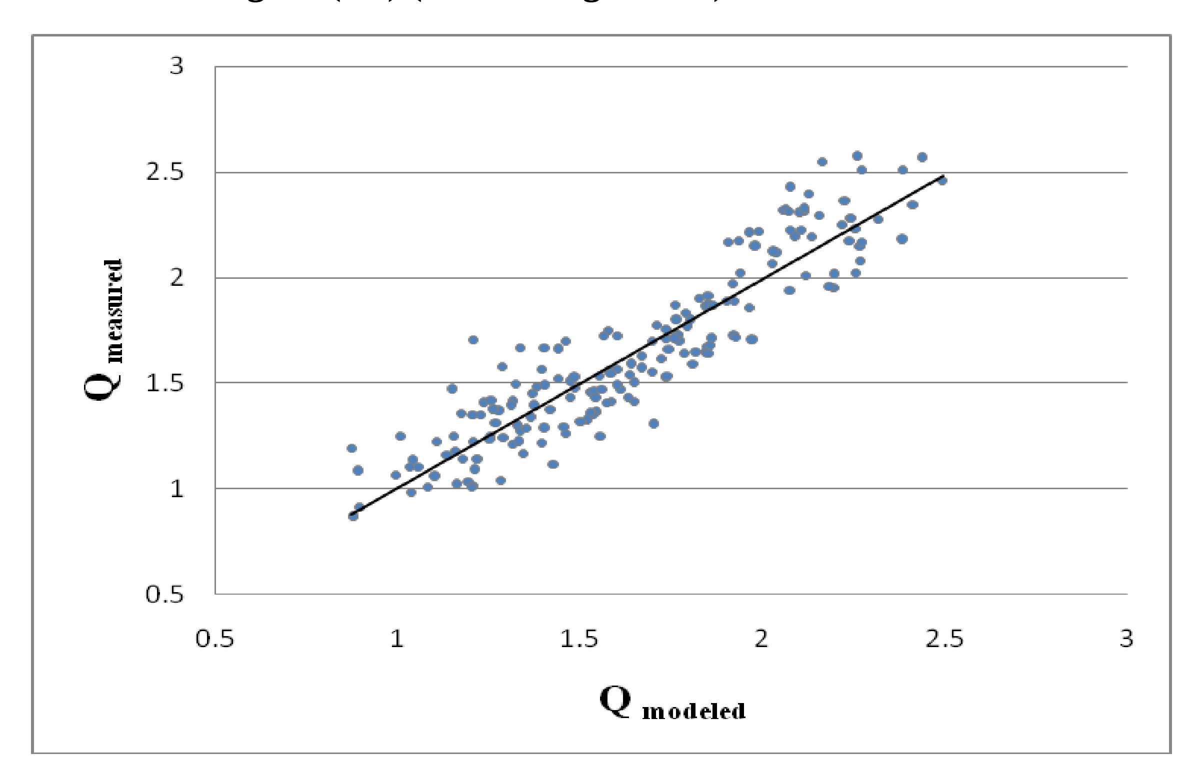
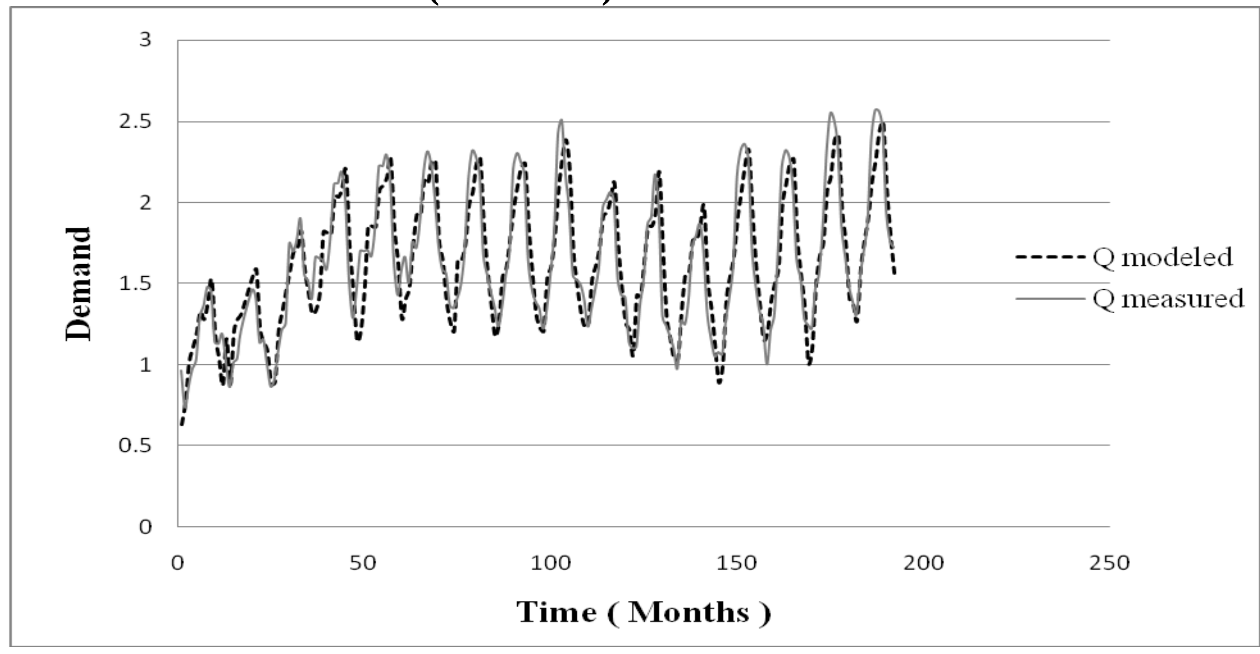


Figure (3.8) shows the comparison between the *Q modeled* and *Q measured*. The results indicate homogeneity between the values of *Q modeled* and *Q measured*.

Moreover, the arithmetic average for *Q modeled* was the same arithmetic mean for *Q measured*, during the year of water demand and was 1.63, which is not showing any large differences compared with the water use *Q modeled* and *Q measured* values. These differences minor between the demand of water for the quantities *Q modeled and Q measured*, to the

presence of many other factors affecting the demand of water than those factors that have been highlighted via this study. So these increases the demand of water during the years that have been mentioned previously due to the increase of population.

Figure(3.8) Water Demand Modeled VS Measured for the period (1990-2005) MCM



3.6 Model Verification Using the Period (2006-2010)

After a cascade model has been developed by two successive development stages using a historical data for the period (1990-2005), the verification of the cascade model for the period (2006-2010) has to be conducted. The available historical data for the period (2006-2010) represented by (population, family income, annual precipitation, monthly precipitation and monthly temperature), will be used to verify the model using the estimated values *(η, a_k, b_k, Φ and β)* from the regression analysis in equation (3.11). The socioeconomic variables related to population growth in thousand, annual income in (JD), annual precipitation in (mm) are shown in Appendix I table (I.2). And monthly precipitation in (mm) and monthly temperature in (C□)are shown in Appendix I table(I.3). The historical data related to total municipal monthly water use time series can be represented as *Q measured* in (MCM) for the period (2006-2010), and the estimated total municipal monthly water use can be represented as *Q modeled* in (MCM) shown in table (3.17). The two values of *Q measured* and *Q modeled* can be compared, as shown in table (3.17) there are differences between the values of *Q measured*, and the values of *Q modeled* for the period (2006-2010), the differences were varied between large, medium and very small, are shown in table (3.17). The reason is due

to the existence of other socioeconomic factors that was not adopted in the development of cascade model stages. The conclusion for the results of development cascade model stages can give a sort of reassurance for the forecast of future monthly water demand. Note that, to estimate total municipal monthly water use *Q modeled* in (MCM), it is necessary to find the components for the development of cascade model stages as Q_a , Q_b , Q_c and Q_d. And then can be shown in Appendix I table (I.4). Then table (3.17) shows the total demand of water measured and modeled.

Table (3.17) Demand of Water Measured Vs Modeled

Year	Month	Q total measured	Q total modeled	Absolute Difference
2006	1	1.4955	1.418953	0.051184888
	2	1.4065	1.271081	0.096280839
	3	1.5795	1.5392	0.025514403
	4	1.759	1.822093	0.035868675
	5	1.94	1.951643	0.006001546
	6	2.405	2.177601	0.094552599
	7	2.56625	2.097045	0.182836824
	8	2.53875	2.088955	0.177171837
	9	2.46125	2.140606	0.130276892
	10	1.97	1.85865	0.056522843
	11	1.7425	1.716595	0.014866571
	12	1.678	1.508312	0.101125149
2007	1	1.6	1.27173	0.20516875
	2	1.5	1.167158	0.221894667
	3	1.61	1.496301	0.070620497
	4	1.81	1.711291	0.054535359
	5	1.99	1.913648	0.038367839
	6	2.4125	2.150011	0.108803731
	7	2.5625	2.08067	0.18803122
	8	2.5125	2.076461	0.173547861
	9	2.4625	2.132722	0.13392
	10	2	1.842577	0.0787115
	11	1.72	1.739308	0.011225581
	12	1.63	1.489495	0.086199387
2008	1	1.45	1.309644	0.096797241
	2	1.48	1.206111	0.185060135
	3	1.7	1.510667	0.111372353
	4	1.8	1.757896	0.023391111
	5	1.83	1.962701	0.072514208
	6	2.475	2.20094	0.110731313
	7	2.625	2.130433955	0.188406112
	8	2.4125	2.127692526	0.118054912
	9	2.4125	2.184321502	0.094581761
	10	1.76	1.900257521	0.079691773
	11	1.73	1.768016312	0.021974747
	12	1.7	1.557486675	0.083831368

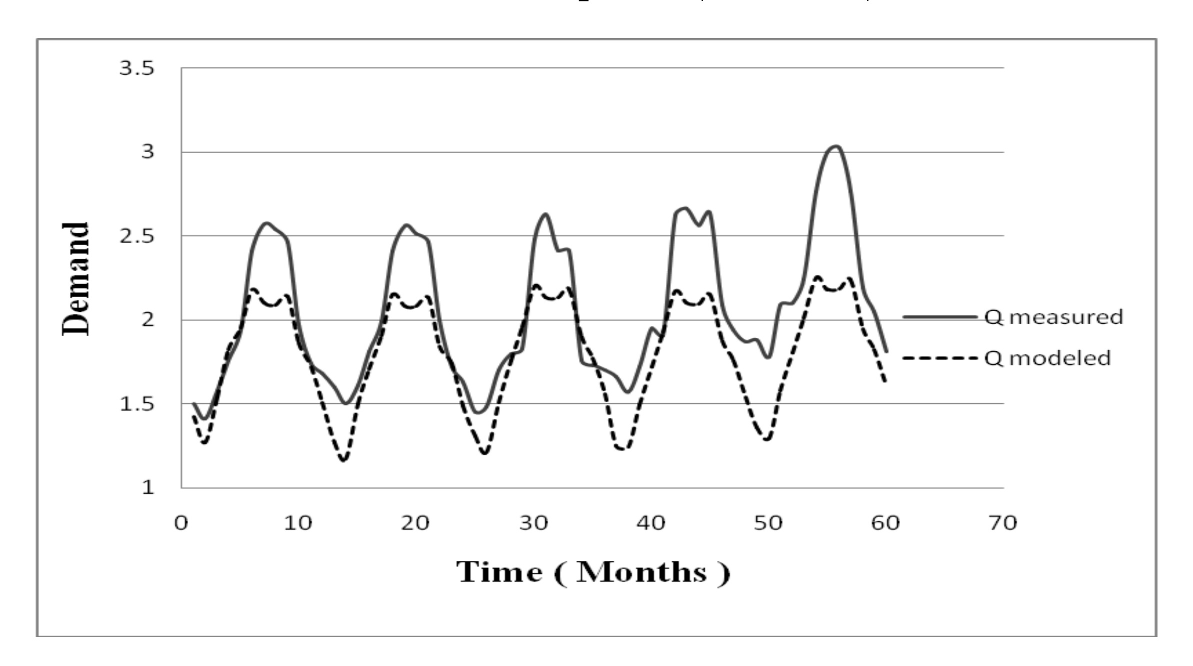
Year	Months	Q total measured	Q total Modeled	Absolute Difference
2009	1	1.66	1.246543462	0.249070204
	2	1.57	1.243217564	0.208141679
	3	1.72	1.496621898	0.12987099
	4	1.95	1.722493404	0.116670049
	5	1.91	1.926762039	0.008775937
	6	2.625	2.168260768	0.173995898
	7	2.6625	2.097311567	0.212277346
	8	2.5625	2.093900418	0.18286813
	9	2.6375	2.149058308	0.185191163
	10	2.09	1.875622226	0.102573098
	11	1.94	1.756083165	0.094802492
	12	1.87	1.537480121	0.177818117
2010	1	1.88	1.361233087	0.275939847
	2	1.78	1.296783063	0.271470189
	3	2.09	1.578038044	0.244957874
	4	2.1	1.806385031	0.139816652
	5	2.24	2.012279021	0.101661151
	6	2.7625	2.250528014	0.185329226
	7	3	2.180879008	0.273040331
	8	3.025	2.181368004	0.27888661
	9	2.7625	2.236201001	0.190515475
	10	2.19	1.945564999	0.111614156
	11	2.05	1.821225997	0.111597075
	12	1.81	1.601972996	0.114932046

Figure (3.9) below shows the differences between the total demand *Q measured* and *Q modeled*. It shows also the amount of demand for the use and consumption of water in Al-Balqa governorate for the period (2006-2010), when using the time series model in equation (3.11) that has been reached, which was the method of verification of the predicted model, to make sure of compatibility with the historical data of quantities of water demand during the years of (2006-2010).

It is clear, there is an increase in the levels of water demand in some months, also there was a decrease in the level of water demand in other months, where the study found that the arithmetic average year, the water demand *Q modeled* by (1.80) which is less than the arithmetic average *Q measured*, which amounted to (2.06). On the other hand, it was predicted in the quantities consumed has reached the highest level of (2.25), which was according to the measured value of the highest record (3.03), the study predicted the lowest water quantities consumed reached to the value of (1.17), which were measured of (1.41). The highest value of the difference between *Q modeled* value and *Q measured* for months during the years (2006-2010), was in August 2010 by (0.28), moreover, it reached a low value of the difference between the *Q modeled* value and *Q measured* for months over the years (2006-2010) was in May 2009 by(0.01).

The study showed over months the result that the lowest value of water use for the months of January to March 2007, and the largest value for water use in the province of survival was for the months of May to October 2010. The figure (3.9) shows also that there are marked increases of demand on water consumption in the governorate through the months of the year related to the study and during the period of (2006-2010).

Figure (3.9) Comparison Between Modeled and measured Monthly Water Demand for the period (2006-2010) MCM



The statistical indicators of residual error shown in table (3.18) for the differences and absolute differences between *Q measured* and *Q modeled* for the period (2006-2010).

Table (3.18) The statistical indicators of residual error

Statistics	Differences	Absolute Differences
Mean	0.1198	0.1279
Std. Error of Mean	0.01115	0.00957
Std. Deviation	0.08636	0.07415
Variance	0.007	0.005
Root Mean of Squared	0.14744	0.14744

3.7 Future Water Demand for the period (2011-2020)

To forecast future values for $Q_a(y)$ forecast, the future socioeconomic factors related to population growth in thousand, annual family income in (JD) and annual precipitation in (mm) have to be made. But the seasonality component $Q_b(m)$ depends only on the month being considered, so the values shown in table (3.9) will be taken as a future values of $Q_b(m)$ for the months from January to December for the period (2011-2020). To calculate future value of deseasonalized water use time series $Q_c(t)$, depends on the last I historical data time series $\{Q_c(t), T- I \leq t \leq T\}$ is what needed to perform the recursive calculation, which is the last I in historical data is December in year 2010, then the value of $Q_c(192)$ will be taken using equation (3.8) to find future $Q_c(t)$ for the period (2011-2020) as shown in Appendix I table(I.6). Finlay to find $Q_d(t)$, forecasts of the future value of climatic variables are necessary.

The future municipal water demand can be predicted by the developed cascade model using equation (3.11) for the period (2011-2020). It is necessary to forecast the future socioeconomic factors related to population, annual family income, annual precipitation, and monthly precipitation and monthly temperature, to compute the expected water use demand. The average rate of growth k for population can be computed from the historical data, shown in table (3.3) and table (I.2) in Appendix I for the period (1990-2010), k = 2.9%, and will be used in equation (3.12) to predict the future population for the period (2011-2020).

$$\text{Pop}(t) = \text{Pop}_0 * (1+k)^n \qquad (3.12)$$

Where k is the rate of growth. Results are shown in table (3.19). The other factor that has to be predicted is annual income in (JD), so it can be computed from the historical data for the period (1990-2010) as shown in table (3.3) and table (I.2) in Appendix I. This factor can be predicted, through linear increasing rate as shown in table (3.18). The last factor that has to be predicted is the annual precipitation (mm), this can be taken as the average value which is related to annual precipitation from the historical data shown in table (3.3) and table (I.2) in Appendix I of the period (1990-2010). The values was (403.85) (mm), and will be assumed as the predicted future value for annual precipitation to find $Q_a(y)$. Table (3.19) shows the predicted future values for socioeconomic factors, the forecasted future values of $Q_a(y)$ shown in Appendix I table (I.5).

Table(3.19) Population growth in thousand, annual family income in (JD), annual precipitation in (mm) for the period (2011-2020)

Year	Population (thousand)	Income (JD)	Precipitation (mm)
2011	421.38	1136.51	403.85
2012	433.60	1167.92	403.85
2013	446.17	1199.33	403.85
2014	459.11	1230.74	403.85
2015	472.42	1262.15	403.85
2016	486.12	1293.56	403.85
2017	500.22	1324.97	403.85
2018	514.73	1356.38	403.85
2019	529.65	1387.79	403.85
2020	545.01	1419.2	403.85

The other components that will be predicted are, the seasonality component $Q_b(m)$ as shown in table (3.9) and the deseasonalized water use time series $Q_c(t)$,and they are shown in Appendix I table (I.6). Finally, the last component that will be predicted is $Q_d(t)$. In order to predict $Q_d(t)$, it is necessary to forecast the future values of climatic variables. In this case it will be taken as an average value which is related to monthly precipitation (mm) and monthly temperature (C□) from the historical data shown in table (3.12), and table (I.3) in Appendix I for the period (1990-2010). And will be assumed as a predicted future values for monthly precipitation (mm) and monthly temperature (C□)to find $Q_d(y)$as shown in Appendix I table I.7). Table (3.20) below, shows the average of monthly precipitation (mm) and monthly temperature (C□), such that the maximum monthly average value of precipitation was in February, and the minimum values was in August and September, and the maximum monthly average value of temperature was in August, and the minimum value was in February.

Table (3.20) Avg. Precipitation & Avg. Temperature *

Month	Avg. Precipitation (mm)	Avg. Temperature (C□)
1	83.97	17.88
2	97.47	16.28
3	93.92	16.46
4	56.77	20.42
5	13.81	25.56
6	3.41	30.29
7	0.2	33.02
8	0	34.44
9	0	34.39
10	0.61	32.39
11	12.8	28.9
12	41.14	22.35

*(Meteorological Department, 2011)

Finally, the future total monthly water use in Al-Baqa governorate for the period (2011-2020) *Q total forecast*, can be predicted by sum of all four components, as shown in table (3.21).

Table (3.21) Q total Forecast for the period (2011-2020) MCM

Year	Month	Q total forecast	Year	Month	Q total forecast
2011	1	1.527021		5	2.38279
	2	1.430371		6	2.618759
	3	1.753996		7	2.549925
	4	1.985033		8	2.548694
	5	2.171557		9	2.608102
	6	2.407526		10	2.318696
	7	2.338692		11	2.199917
	8	2.337461		12	1.978389
	9	2.396869	2013	1	1.967862
	10	2.107463		2	1.871212
	11	1.988684		3	2.194837
	12	1.767156		4	2.425874
2012	1	1.738254		5	2.612398
	2	1.641604		6	2.848367
	3	1.965229		7	2.779533
	4	2.196266		8	2.778302

follow

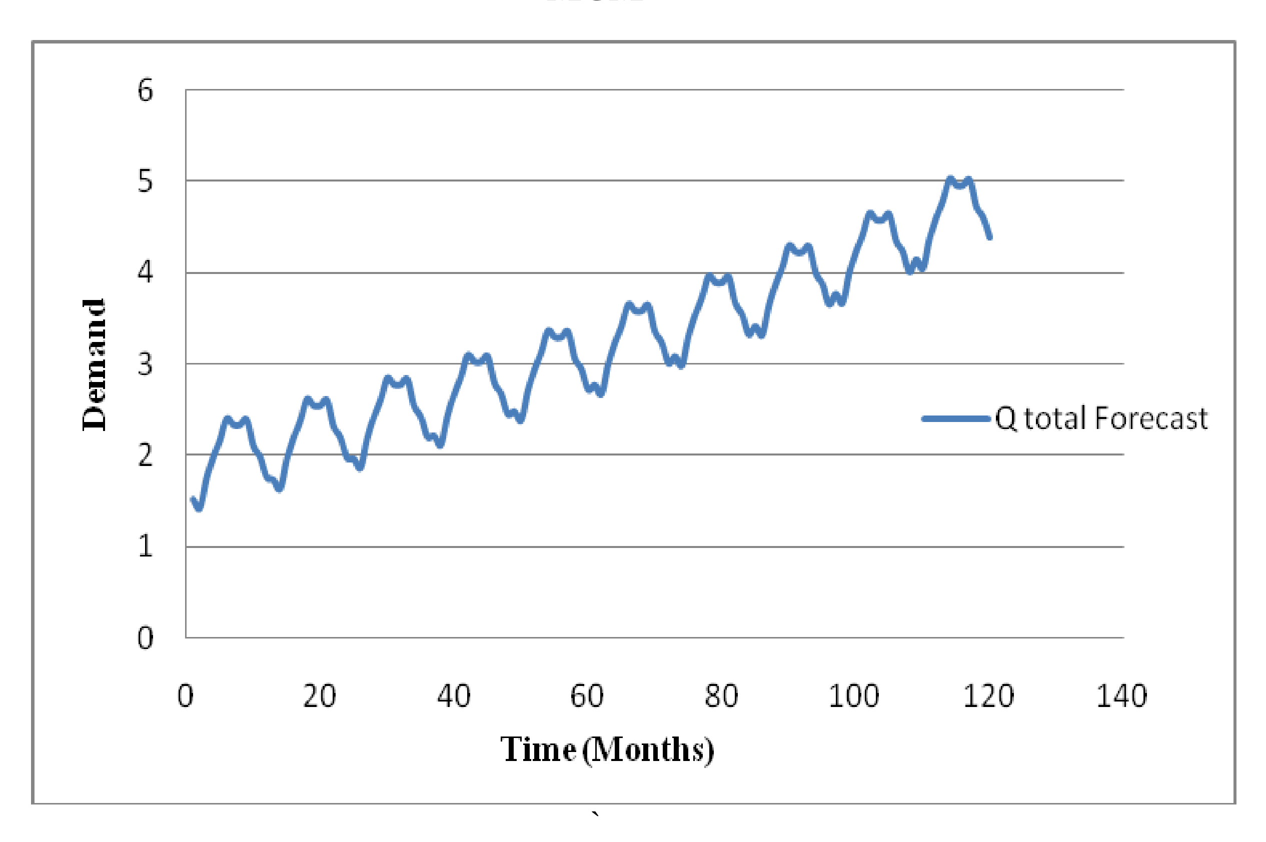
Year	Month	Q total forecast	Year	Month	Q total forecast
	9	2.83771		12	3.014421
	10	2.548304	2017	1	3.084219
	11	2.429525		2	2.987569
	12	2.207997		3	3.311194
2014	1	2.216895		4	3.542231
	2	2.120245		5	3.728755
	3	2.44387		6	3.964724
	4	2.674907		7	3.89589
	5	2.861431		8	3.894659
	6	3.0974		9	3.954067
	7	3.028566		10	3.664661
	8	3.027335		11	3.545882
	9	3.086743		12	3.324354
	10	2.797337	2018	1	3.415677
	11	2.678558		2	3.319027
	12	2.45703		3	3.642652
2015	1	2.485353		4	3.873689
	2	2.388703		5	4.060213
	3	2.712328		6	4.296182
	4	2.943365		7	4.227348
	5	3.129889		8	4.226117
	6	3.365858		9	4.285525
	7	3.297024		10	3.996119
	8	3.295793		11	3.87734
	9	3.355201		12	3.655812
	10	3.065795	2019	1	3.76866
	11	2.947016		2	3.67201
	12	2.725488		3	3.995635
2016	1	2.774286		4	4.226672
	2	2.677636		5	4.413196
	3	3.001261		6	4.649165
	4	3.232298		7	4.580331
	5	3.418822		8	4.5791
	6	3.654791		9	4.638508
	7	3.585957		10	4.349102
	8	3.584726		11	4.230323
	9	3.644134		12	4.008795
	10	3.354728	2020	1	4.144743
	11	3.235949		2	4.048093

follow

Year	Month	Q total forecast	Year	Month	Q total forecast
	3	4.371718		8	4.955183
	4	4.602755		9	5.014591
	5	4.789279		10	4.725185
	6	5.025248		11	4.606406
	7	4.956414		12	4.384878

Figure (3.10) Shows the *Q modeled* forecasts in Al-Balqa governorate, for the period (2011-2020), incase taking an average of climatic factors, which is expected to increase of *Q modeled* forecast, as a result of increase the number of population, which is expected to reach about of 55.62 MCM in year 2020. Also there is an increase of municipal water demand reach to its highest value (5.025) in June 2020. On the other hand, the lowest value of *Q modeled* forecast was (1.43) in February 2011. Therefore, which require the development of specialized programs and methods to reduce of water demand in Al-Balqa governorate, due to increase of population, where it reaches to 545010 persons in 2020.

Figure (3.10) Predicted Water Demand for the period (2011-2020) MCM



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Chapter Four
Water Demand Management

4.1 Introduction

The growing demand on water for different purposes is due to several factors such as population growth, rising living levels, technological advances and industrial progress had had a significant impact on that as well as the real problem of water shortage for different purposes which affect the rates of water supply and water supply to the beneficiaries as it is considered one of the obstacles facing decision-makers in the provision of water to the beneficiaries. Decision-makers seek to find many ways and procedures for the sake of access to other sources of water to help filling the shortage of water supply and provide the best possible ways and means to improve efficiency and reduce the depletion of water sources and finding alternative sources for those traditional sources(Arabiyat, 2002). Water demand management may be defined as
Water Demand Management (WDM): is a set of followed measures and policies that will control or influence in how the demand for water used for different purposes and strategies through a complete help to reduce the depletion of water resources and raise the efficiency of water use and provide the possible means and ways(Arafa, 2005, Hijazi, 2010, Savenije & Zaag, 2002).

In Jordan WDM can be stated as a set of policies and procedures by the concerned institutions in Jordan and in Al-Balqa governorate, which would preserve the water resources, the rationalization of water consumption and increase the awareness of citizens of the need to review the uses of water and find alternative sources for the traditional to reduce the shortage in the supply, reuse of treated wastewater, use the latest methods that contribute to raising the efficiency and the provision of water to achieve equity in water distribution in economic efficiency, environmental protection and sustainability of water resources for the purposes of supply.

To maintain the water sources in Jordan, which is scarce, the Jordanian government in 2002 established a unit of Water Demand Management in the Ministry of Water and Irrigation, by issuing of various policies and measures that would preserve the water resources and raise efficiency of use in addition to studies of water that would clarify the reality of Water Demand in Jordan.

4.2 Importance of Water Demand Management in Jordan

The water problem in Jordan is one of the most important future challenges that the country face , as the administration suffers from poor

and underdeveloped stuff of scientific and technical, which reflected negatively on the (supply and demand) which exceeded the water uses the actual width of the quantities available and depriving many residents of the water due to their steady growth. the impact of poor water management is not considered only on the equitable distribution of water to the population, but also on the development of water resources, which said Jordan suffers from, with the increasing negative effects on the effective management of water, including the delivery to main consumption centers and the inability to implement projects, which are the basis for water development for many years; emerged as a problem of funding and provide financial and material support to these projects which are a heavy burden on the governorate to re-administrate and reform relations and development that are necessary, (Al-Rubai, 2009).

The financial costs amounted to large numbers of transport and delivery, etc., as the public budgets of the governorate and financial constraints negatively affect the national economy. So the great difficulties facing the policy of demand management to water clearly indicate the depth of the challenges facing the reality in Jordan, which requires consideration of new strategies for water in the future to be carefully selected by taking many of the necessary measures to address water shortages in Jordan. The Strategy clearly is to focus on increasing the supply of safe drinking water provided to the beneficiaries, another strategy cares about reducing the large increase in the demand of water for agriculture and irrigation and the use of alternative methods that will raise the efficiency of wastewater, improved and reused for irrigation and agriculture. (Arabiyat 2002).

4.3 Best Management Practice

4.3.1 Introduction

Al-Balqa governorate depends on groundwater mainly for household supplies, where most houses connected by a network of pipes for water distribution, the Ministry of Water and Irrigation, has implemented a series of measures to reform the old network and improve the effectiveness of the water distribution system.

The use of municipal water is not limited to houses only, but extends to the use of government offices, hospitals, commercial and tourist purposes. These uses shows that the ability to achieve abundance in the water by the best practices to use, has been developed by successive governments, so the stakeholders and workers in the water sector, designers, builders and suppliers of water and operators are responsible for best management practices to increase efficiency through new technologies

and the use of alternatives in the multiple water sources repair leaks, monitor water meters and sewage treatment, (Hoffman & sha’ban, 2011).

4.3.2 Why Save Water Use

The meaning of reducing water use is the ways that excessive lead to the depletion of working on water conservation and availability for future generations, and this leads to save money and provide the monthly bill for water, in addition to reducing the amount of waste water emerging to the purification stations , which also means less energy used in pumping Water and get more recycling of water, where it is used only for agricultural and industrial purposes, (Hoffman &sha’ban, 2011).

Water conservation means that use help in obtaining international recognition and puts the relevant institutions in the attitudes of good to the competition for prizes and large national prize of King Abdullah of excellence in water use efficiency, in addition to those awards and international accreditations in the field of green buildings, as put Jordan at the forefront of competition in the field of the best tools used to manage water demand, (KAIIC, 2010).

It is noble causes in the conservation of water use those for future generations, every drop of water is provided more opportunities for supply to other users who need it, especially during water shortages and drought, as it is the responsibility of the national joint public and private sectors and the citizens.

4.3.3 Determine the Best Management Practices

The identification of best management practices is a set of processes and training process that includes many of the recommendations that help identify opportunities and implement programs to provide water, with the development of best management practices for different categories of water use, in addition to the mind set of actions that increase the efficiency of water use both for internal home use or external ,as a way to save water, (Zureikat & Husseini, 2011).

Application of such practices are based on inclusive national plans that include the following:

1. Continue to structuring water tariff and it make possible to save water, it is used as an economic tax tool in order to provide on intensive to save the water. By this tariff and specification of the price of water unit increase the available water through saving, because the price of water is related to the used quantities of water and decreases the amount of water invoice.

2. Increase the citizens' awareness about the importance of water as an essential commodity in the community through the media campaigns, through TV programs, advertisements and guidelines, Broadcasting stations, and news papers to explain the water status and how to participate in the efforts of saving the water and using water more efficiently.
3. The private sector must participate in the supply systems. It is like the public sector must save and protect the water resources from depletion, through the private sector's practices and providing the programs that are necessary to save water such as increase the efficiency of the system and control the leakage and decrease the water loss, and improve the administrative practices in distributing the water and the international standards and pricing, in addition of improving the customers' service, and the general education in regard of preserve the environment and overcome the illegal connections.
4. Teaching the principles of demand on water in the school to the students and the ideal usage methods of the available water, in order to increase the awareness of understanding the importance of water and how to preserve it and explaining its scarcity in Jordan.
5. Make the concept of management of water demand a basic factor in the vision of the top management of water, through using new laws that aim at preserving the water by increasing the efficiency and improving the justice in distribution, usage, and updating the treatment of water problem, and making the concerned parties responsible of managing the demand on water and they should enjoy the self dependency.
6. Using the modern technical methods and the devices that save water at house, such as regulating the use of water through taps, and using the pieces that save water and splashes, without affecting the user comfort. Such pieces are easy to be used and maintained and such methods are considered from the best methods used to preserve water at houses.
7. Selecting certain types of plants which need less quantities of water, and can bear the hot and dry conditions and don't need large quantities of water, such plants must be able to adjust according to the climate and topography of Al-Balqa governorate, which is cold and raining in winter and moderate in summer.
8. The irrigation system and harvesting the rainfall water are important elements in term of using water efficiently and wisely. They constitute one of the basic contents of designing the successful programs for the parks. Such systems that are used in the various parks increase the usage efficiency and decrease water consumption.

The irrigation system and its timing limits water loss, in addition that the weekly irrigation increases the plant growth, while the continuous irrigation leaves the soil humid at the surface, and therefore the plant's roots would stay near the surface and this would weaken the plant, especially in the clayey soil, which needs a period of time in order that the water enters it deeply, and not to be kept near the surface.

9. Treatment of waste water and reusing it, and reusing the gray water resulted of the houses for the agricultural purposes. In addition of setting the laws and procedures necessary for recycling the water wherever it is possible for the nondrinking water in the urbanized areas.

10. Setting polices for managing the water demand in the agricultural sector that limit the extreme usage of water and concentrate on using the untraditional instead of groundwater, which has been depleted for the agricultural purposes especially in the Jordan valley.

11. Observation of water providers to the factories and maintain them continuously, in order to detect the defects, leakages, and the old worn networks and repair them.

(Abdelkhaleq, 2008,KAIIC, 2010, Sha'ban & etal, 2009, Sheikh &etal, 2010, Zureikat & Husseini, 2011).

Chapter Five
Conclusions and Recommendations

5.1 Conclusions

From the present work, the following main points have been concluded:

1. The main problem for Al-Balqa governorate is the scarcity of water under the difficult water circumstances due to the change of the rainfall rate and its fluctuation from one year to another and the necessity to provide water needs by many administrative procedures in regard with demand management of water, and to increase the awareness of citizens to follow the practices that save water consumption in the various fields such as rain water harvesting and reuse treated wastewater.
2. To forecast monthly municipal water use in Al-Balqa governorate for the period (2011-2020). The historical data for the period (1990-2005) has to be used, related to monthly municipal water use as a dependent variable and socioeconomic factors and climatic factors as independent variables. The correlation coefficients between water demand and these factors are indicted that the main factor affecting on water demand forecasting is population, which will reach to 545010 inhabitants in 2020.
3. Before forecasting the monthly municipal water use in Al-Balqa governorate for the period (2011-2020), two steps of analysis have to be used. First, accuracy of model for the period (1990-2005), second, model verification for the period (2006-2010), these steps of analysis can be compared between values of *Q measured* and *Q modeled,* in which the last one is estimated using time series analysis. The results shows that there are a differences between the values of *Q measured* and *Q modeled,* the differences were varied between large, medium and very small. These two steps give the cascade model a sort of confidence in the forecast of future monthly water use.
4. The reason for these above differences between *Q measured* and *Q modeled* is due to the existence of other socioeconomic factors that was not adopted in the development of cascade model stages.
5. There is a significant increase of water demand for the future years from 2011-2020, which will reached to 55.65 million cubic meter in 2020. The increase of water demand is due to the increase of population in the years of study, as a result of the natural increase of population, increase of births, the improvement of health services and reduction of deaths numbers in addition to the demographic factors that tempt to the neighbor countries due to the wars.

5.2 Recommendations

The following points can be recommended for future works:

1. The necessity to observe the water networks and distribution, with the regular maintenance of such networks, and detecting the illegal water use and the leakages in order to save the water and to limit the lost water and to punish the violators.
2. The necessity of awareness the citizens through the advertising campaigns by encouraging the modern management means and tools and using the technological devices to limit the consumption and use the water harvest method in order to gather the water.
3. Continue to use an ascending slides of water tariff in order to limit water depletion for all the municipal, industrial and agricultural sectors.
4. Construct a new dams to gather water in certain areas, in order to use such water in the various purposes and to protect the neighborhood areas from floods.
5. Treatment of waste water, in order to reusing it for various purposes in the agricultural sector.
6. Planting the crops that do not need large quantities of water in order to preserve the water resources, especially, in the Jordan Valley.
7. The necessity that both public, private sectors and the concerned parties to participate in limiting the depletion of water resources and to increase the efficiency of use, in addition to using the best management means to limit the illegal use of water.
8. The necessity of setting the various programs in order to control the birth and to limit the large growth of the natural increase of the population, especially, that Jordan suffers from the sudden emigrations of populations as a result of the regional situations in the middle east.

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Appendix I

Tables

Table (I.1) Value of Q_a, Q_b, Q_c, and Q_d for the period (1990-2005)

Month	Q_a	Q_b	Q_c	Q_d
1	1.032455	-0.41867	-0.002	0.01865
2	1.032455	-0.51967	0.262289	-0.00545
3	1.032455	-0.19454	0.169666	0.007175
4	1.032455	0.049132	0.024339	-0.00253
5	1.032455	0.249426	-0.07694	-0.01028
6	1.032455	0.4835	-0.1846	-0.00585
7	1.032455	0.412176	-0.16298	-0.00338
8	1.032455	0.408915	-0.05826	-0.003
9	1.032455	0.468398	0.030296	-0.0069
10	1.032455	0.181687	-0.03231	-0.0063
11	1.032455	0.062048	-0.0529	-0.00208
12	1.032455	-0.16383	0.027604	-0.0244
13	1.304273	-0.41867	0.240182	0.033125
14	1.304273	-0.51967	0.098528	-0.00553
15	1.304273	-0.19454	0.06148	0.03545
16	1.304273	0.049132	-0.06829	-0.0052
17	1.304273	0.249426	-0.22958	-0.0097
18	1.304273	0.4835	-0.25203	-0.00525
19	1.304273	0.412176	-0.22134	-0.00405
20	1.304273	0.408915	-0.16941	-0.00405
21	1.304273	0.468398	-0.18367	-0.00593
22	1.304273	0.181687	-0.26479	-0.00423
23	1.304273	0.062048	-0.25519	0.025575
24	1.304273	-0.16383	-0.15098	0.09055
25	1.366841	-0.41867	-0.09771424	0.026525
26	1.366841	-0.51967	-0.062268726	0.10845
27	1.366841	-0.19454	0.045178117	-0.007475
28	1.366841	0.049132	-0.066804455	-0.01855
29	1.366841	0.249426	-0.149556515	-0.009
30	1.366841	0.4835	-0.268334664	-0.0057
31	1.366841	0.412176	-0.078693511	-0.00525
32	1.366841	0.408915	-0.062892229	-0.003

Month	Q_a	Q_b	Q_c	Q_d
33	1.366841	0.468398	-0.004901074	-0.006825
34	1.366841	0.181687	0.043647065	-0.008475
35	1.366841	0.062048	0.004160058	0.0063
36	1.366841	-0.16383	0.063172344	0.046
37	1.593449	-0.41867	0.14903876	0.01175
38	1.593449	-0.51967	0.364547274	0.00125
39	1.593449	-0.19454	0.433462117	-0.01415
40	1.593449	0.049132	0.183653545	-0.015825
41	1.593449	0.249426	-0.036924515	-0.006025
42	1.593449	0.4835	-0.033437664	-0.004425
43	1.593449	0.412176	0.028751489	-0.003825
44	1.593449	0.408915	0.085307771	-0.0021
45	1.593449	0.468398	0.139593926	-0.00575
46	1.593449	0.181687	-0.036010435	-0.00515
47	1.593449	0.062048	-0.184053942	-0.0151
48	1.593449	-0.16383	-0.269536656	-0.014475
49	1.553582	-0.41867	0.02825576	0.0426
50	1.553582	-0.51967	0.422345274	0.002775
51	1.553582	-0.19454	0.494965117	0.003825
52	1.553582	0.049132	0.259235545	-0.009975
53	1.553582	0.249426	0.052736485	-0.00795
54	1.553582	0.4835	0.043626336	-0.00585
55	1.553582	0.412176	0.140827739	-0.00435
56	1.553582	0.408915	0.192752771	-0.00285
57	1.553582	0.468398	0.247965176	-0.00185
58	1.553582	0.181687	0.094590815	0.011375
59	1.553582	0.062048	-0.064011942	0.0773
60	1.553582	-0.16383	-0.134674656	0.029075
61	1.70087	-0.41867	0.14162876	-0.0212
62	1.70087	-0.51967	0.283778274	0.005575
63	1.70087	-0.19454	0.239320117	-0.01315
64	1.70087	0.049132	0.185135545	-0.012525

Month	Q_a	Q_b	Q_c	Q_d
65	1.70087	0.249426	-0.022845515	-0.0082
66	1.70087	0.4835	-0.047516664	-0.003975
67	1.70087	0.412176	0.004668989	-0.00405
68	1.70087	0.408915	0.149219021	-0.002925
69	1.70087	0.468398	0.088650176	-0.0048
70	1.70087	0.181687	-0.109184185	-0.011575
71	1.70087	0.062048	-0.113658942	-0.011825
72	1.70087	-0.16383	-0.130969656	-0.0141
73	1.619573	-0.41867	0.02010476	0.038625
74	1.619573	-0.51967	0.124463274	-0.01725
75	1.619573	-0.19454	0.183745117	0.037725
76	1.619573	0.049132	-0.011229455	-0.012875
77	1.619573	0.249426	-0.127326515	-0.0072
78	1.619573	0.4835	-0.117170664	-0.005175
79	1.619573	0.412176	0.029677739	-0.0018
80	1.619573	0.408915	0.210351521	-0.0021
81	1.619573	0.468398	0.186832676	-0.004725
82	1.619573	0.181687	0.055688315	-0.00295
83	1.619573	0.062048	-0.092910942	-0.014
84	1.619573	-0.16383	-0.093178656	0.00415
85	1.583396	-0.41867	-0.00508924	0.012425
86	1.583396	-0.51967	0.144470274	0.0431
87	1.583396	-0.19454	0.131134117	0.02075
88	1.583396	0.049132	-0.020862455	-0.0177
89	1.583396	0.249426	-0.056190515	-0.003175
90	1.583396	0.4835	-0.100868664	-0.0051
91	1.583396	0.412176	0.105630239	-0.003
92	1.583396	0.408915	0.229802771	-0.0057
93	1.583396	0.468398	0.193316426	-0.006475
94	1.583396	0.181687	0.090885815	-0.0041
95	1.583396	0.062048	-0.089205942	0.00465
96	1.583396	-0.16383	-0.130228656	0.0207

Month	Q_a	Q_b	Q_c	Q_d
97	1.646684	-0.41867	-0.02065024	0.01865
98	1.646684	-0.51967	0.085190274	-0.006925
99	1.646684	-0.19454	0.068149117	0.01565
100	1.646684	0.049132	-0.082365455	-0.012675
101	1.646684	0.249426	-0.100650515	-0.00815
102	1.646684	0.4835	-0.050480664	-0.00495
103	1.646684	0.412176	0.214001489	-0.0015
104	1.646684	0.408915	0.328911521	0.00015
105	1.646684	0.468398	0.085871426	-0.00395
106	1.646684	0.181687	-0.124930435	-0.008125
107	1.646684	0.062048	-0.207765942	-0.014725
108	1.646684	-0.16383	-0.140602656	-0.02015
109	1.633967	-0.41867	0.00676676	0.01155
110	1.633967	-0.51967	0.141506274	-0.0033
111	1.633967	-0.19454	0.092602117	-0.006
112	1.633967	0.049132	-0.063099455	-0.01155
113	1.633967	0.249426	-0.156225515	-0.0066
114	1.633967	0.4835	-0.196457664	-0.00585
115	1.633967	0.412176	-0.107407261	-0.002625
116	1.633967	0.408915	-0.018432229	-0.00135
117	1.633967	0.468398	0.017328926	-0.005025
118	1.633967	0.181687	-0.066576685	-0.00905
119	1.633967	0.062048	-0.209247942	-0.016775
120	1.633967	-0.16383	-0.195436656	-0.017825
121	1.615955	-0.41867	-0.03695224	0.053025
122	1.615955	-0.51967	-0.045225726	0.0064
123	1.615955	-0.19454	0.001459117	0.004675
124	1.615955	0.049132	-0.232047455	-0.014225
125	1.615955	0.249426	-0.220692515	-0.009825
126	1.615955	0.4835	-0.246104664	-0.00405
127	1.615955	0.412176	-0.177802261	0.00145
128	1.615955	0.408915	-0.089753479	-0.002775

Month	Q_a	Q_b	Q_c	Q_d
129	1.615955	0.468398	0.106248926	-0.005675
130	1.615955	0.181687	-0.097142935	0.000175
131	1.615955	0.062048	-0.371526942	-0.016375
132	1.615955	-0.16383	-0.325852656	0.029675
133	1.652678	-0.41867	-0.20812324	0.00545
134	1.652678	-0.51967	-0.096354726	-0.00335
135	1.652678	-0.19454	-0.112654883	-0.012425
136	1.652678	0.049132	-0.136458455	-0.009175
137	1.652678	0.249426	-0.334065515	0.0024
138	1.652678	0.4835	-0.366887664	-0.0027
139	1.652678	0.412176	-0.299141011	-0.00135
140	1.652678	0.408915	-0.198124729	-0.001875
141	1.652678	0.468398	-0.142912324	-0.005775
142	1.652678	0.181687	-0.310180435	-0.0065
143	1.652678	0.062048	-0.379677942	0.007275
144	1.652678	-0.16383	-0.406102956	0.02065
145	1.567871	-0.41867	-0.32075524	0.058875
146	1.567871	-0.51967	-0.054117726	-0.000625
147	1.567871	-0.19454	0.010351117	0.0191
148	1.567871	0.049132	-0.069768455	-0.002775
149	1.567871	0.249426	-0.141405515	-0.008375
150	1.567871	0.4835	-0.142364664	-0.005025
151	1.567871	0.412176	0.081547739	-0.0006
152	1.567871	0.408915	0.252032771	-0.00255
153	1.567871	0.468398	0.282236426	-0.003675
154	1.567871	0.181687	0.175174565	-0.0004
155	1.567871	0.062048	-0.026961942	-0.003775
156	1.567871	-0.16383	-0.109480656	0.06785
157	1.626134	-0.41867	-0.05547724	-0.00085
158	1.626134	-0.51967	0.025169274	0.067725
159	1.626134	-0.19454	-0.079309883	0.0392
160	1.626134	0.049132	-0.165357455	-0.0075

Month	Q_a	Q_b	Q_c	Q_d
161	1.626134	0.249426	-0.270339515	-0.00435
162	1.626134	0.4835	-0.117911664	-0.004875
163	1.626134	0.412176	0.076916489	-0.002475
164	1.626134	0.408915	0.206646521	-0.001275
165	1.626134	0.468398	0.176643926	-0.006075
166	1.626134	0.181687	-0.014706685	-0.0093
167	1.626134	0.062048	-0.126996942	-0.009925
168	1.626134	-0.16383	-0.117631656	0.005925
169	1.528622	-0.41867	-0.13476424	0.0308
170	1.528622	-0.51967	0.100751274	-0.0059
171	1.528622	-0.19454	0.157810117	-0.0075
172	1.528622	0.049132	0.103625545	-0.01495
173	1.528622	0.249426	-0.009507515	-0.0095
174	1.528622	0.4835	0.063633336	-0.00555
175	1.528622	0.412176	0.221411489	-0.0009
176	1.528622	0.408915	0.448397771	-0.00345
177	1.528622	0.468398	0.420247676	-0.0039
178	1.528622	0.181687	0.256684565	-0.00485
179	1.528622	0.062048	0.106418058	0.047225
180	1.528622	-0.16383	0.050575344	-0.0142
181	1.66967	-0.41867	0.08753576	0.032125
182	1.66967	-0.51967	0.101492274	0.018425
183	1.66967	-0.19454	0.118537117	-0.008
184	1.66967	0.049132	0.052496545	-0.0107
185	1.66967	0.249426	-0.010248515	-0.008625
186	1.66967	0.4835	-0.023804664	-0.005625
187	1.66967	0.412176	0.178803989	-0.001875
188	1.66967	0.408915	0.359477771	-0.001875
189	1.66967	0.468398	0.358188926	-0.0051
190	1.66967	0.181687	0.236307065	-0.0105
191	1.66967	0.062048	0.063440058	-0.0021
192	1.66967	-0.16383	0.022417344	0.034775

Table (I.2) Population growth thousand, annual income (JD), annual precipitation(mm) (2006-2010)

Year	Population* thousand	Income JD**	Precipitation*** mm
2006	375.2	979.46	396.15
2007	383.4	1010.87	368.35
2008	391.9	1042.28	251.6
2009	400.6	1073.69	448.55
2010	409.5	1105.1	293.85

(*,**Yearly Reports of Dep. of Statistics from2006-2009,statistical book,2010,***Dep. of Meteorological., 2011)

Table (I.3) Precipitation & Temperature for the period (2006-2010)

Year	Months	Precipitation	Temperature
2006	1	79.45	15.3
	2	67.05	17.3
	3	5.75	21.3
	4	125.1	23.65
	5	0.1	30
	6	0	33.4
	7	0	33.75
	8	0	35.35
	9	0	33.7
	10	34.7	27.95
	11	15.25	21.45
	12	68.75	16.8
2007	1	95.35	15.5
	2	86.25	16.95
	3	88.55	19.45
	4	17.8	24.35
	5	1.6	31.45
	6	0	33.75
	7	0	35.25
	8	0	34.75
	9	0	32.7
	10	1.15	30.1
	11	53.85	23.5
	12	23.8	17.6
2008	1	85.15	13.2
	2	70.7	16.35
	3	4.4	24.75
	4	0	28.6
	5	5.9	29.65
	6	0	34.4

Year	Months	Precipitation	Temperature
	7	0	34.95
	8	0	35.3
	9	1.5	32.9
	10	22.25	27.75
	11	7.85	24.15
	12	53.85	19.05
2009	1	12.65	17.15
	2	206.95	17.5
	3	60.65	18.45
	4	4.8	25.2
	5	0	29.45
	6	0	34.4
	7	0	34.65
	8	0	34.55
	9	0.2	31.6
	10	26.45	31.7
	11	56.2	21.85
	12	80.65	18.55
2010	1	71.9	18.3
	2	142	19.3
	3	44.05	22.7
	4	0.95	26.85
	5	0.75	30.65
	6	0.7	33.45
	7	0	34.8
	8	0	37.3
	9	0	34.2
	10	0.1	31.55
	11	0.45	28.3
	12	37.85	20.25

*(Department of meteorological 2011)

Table (I.4) Value of Q_a, Q_b, Q_c, and Q_d for the period (2006-2010)

Year	Month	Q_a	Q_b	Q_c	Q_d
2006	1	1.668053	-0.41867	0.16089476	0.008675
	2	1.668053	-0.51967	0.117223017	0.005475
	3	1.668053	-0.19454	0.084862256	-0.019175
	4	1.668053	0.049132	0.060882931	0.044025
	5	1.668053	0.249426	0.043114252	-0.00895
	6	1.668053	0.4835	0.029947661	-0.0039
	7	1.668053	0.412176	0.020191217	-0.003375
	8	1.668053	0.408915	0.012961692	-0.000975
	9	1.668053	0.468398	0.007604613	-0.00345
	10	1.668053	0.181687	0.003635019	0.005275
	11	1.668053	0.062048	0.000693549	-0.0142
	12	1.668053	-0.16383	-0.00148608	0.005575
2007	1	1.676576	-0.41867	-0.003101186	0.016925
	2	1.676576	-0.51967	-0.004297978	0.01455
	3	1.676576	-0.19454	-0.005184802	0.01945
	4	1.676576	0.049132	-0.005841938	-0.008575
	5	1.676576	0.249426	-0.006328876	-0.006025
	6	1.676576	0.4835	-0.006689697	-0.003375
	7	1.676576	0.412176	-0.006957066	-0.001125
	8	1.676576	0.408915	-0.007155186	-0.001875
	9	1.676576	0.468398	-0.007301993	-0.00495
	10	1.676576	0.181687	-0.007410777	-0.008275
	11	1.676576	0.062048	-0.007491385	0.008175
	12	1.676576	-0.16383	-0.007551117	-0.0157
2008	1	1.727534	-0.41867	-0.007595377	0.008375
	2	1.727534	-0.51967	-0.007628175	0.005875
	3	1.727534	-0.19454	-0.007652477	-0.014675
	4	1.727534	0.049132	-0.007670486	-0.0111
	5	1.727534	0.249426	-0.00768383	-0.006575
	6	1.727534	0.4835	-0.007693718	-0.0024
	7	1.727534	0.412176	-0.007701045	-0.001575
	8	1.727534	0.408915	-0.007706474	-0.00105

Year	Month	Q_a	Q_b	Q_c	Q_d
	9	1.727534	0.468398	-0.007710498	-0.0039
	10	1.727534	0.181687	-0.007713479	-0.00125
	11	1.727534	0.062048	-0.007715688	-0.01385
	12	1.727534	-0.16383	-0.007717325	0.0015
2009	1	1.694882	-0.41867	-0.007718538	-0.02195
	2	1.694882	-0.51967	-0.007719436	0.075725
	3	1.694882	-0.19454	-0.007720102	0.004
	4	1.694882	0.049132	-0.007720596	-0.0138
	5	1.694882	0.249426	-0.007720961	-0.009825
	6	1.694882	0.4835	-0.007721232	-0.0024
	7	1.694882	0.412176	-0.007721433	-0.002025
	8	1.694882	0.408915	-0.007721582	-0.002175
	9	1.694882	0.468398	-0.007721692	-0.0065
	10	1.694882	0.181687	-0.007721774	0.006775
	11	1.694882	0.062048	-0.007721835	0.006875
	12	1.694882	-0.16383	-0.007721879	0.01415
2010	1	1.778225	-0.41867	-0.007721913	0.0094
	2	1.778225	-0.51967	-0.007721937	0.04595
	3	1.778225	-0.19454	-0.007721956	0.002075
	4	1.778225	0.049132	-0.007721969	-0.01325
	5	1.778225	0.249426	-0.007721979	-0.00765
	6	1.778225	0.4835	-0.007721986	-0.003475
	7	1.778225	0.412176	-0.007721992	-0.0018
	8	1.778225	0.408915	-0.007721996	0.00195
	9	1.778225	0.468398	-0.007721999	-0.0027
	10	1.778225	0.181687	-0.007722001	-0.006625
	11	1.778225	0.062048	-0.007722003	-0.011325
	12	1.778225	-0.16383	-0.007722004	-0.0047

Table (I.5) $Q_a(y)$ Values for the period (2011-2020)

Year	$Q_{a}(y)$
2011	1.938608
2012	2.149841
2013	2.379449
2014	2.628482
2015	2.89694
2016	3.185873
2017	3.495806
2018	3.827264
2019	4.180247
2020	4.55633

Table (I.6) $Q_c(m,y)$ values for the period (2011-2020)

Year	Month	$Q_c(m,y)$	Year	Month	$Q_c(m,y)$
2011	1	-0.007722005		7	-0.007722008
	2	-0.007722006		8	-0.007722008
	3	-0.007722006		9	-0.007722008
	4	-0.007722007		10	-0.007722008
	5	-0.007722007		11	-0.007722008
	6	-0.007722007		12	-0.007722008
	7	-0.007722007	2014	1	-0.007722008
	8	-0.007722007		2	-0.007722008
	9	-0.007722007		3	-0.007722008
	10	-0.007722008		4	-0.007722008
	11	-0.007722008		5	-0.007722008
	12	-0.007722008		6	-0.007722008
2012	1	-0.007722008		7	-0.007722008
	2	-0.007722008		8	-0.007722008
	3	-0.007722008		9	-0.007722008
	4	-0.007722008		10	-0.007722008
	5	-0.007722008		11	-0.007722008
	6	-0.007722008		12	-0.007722008
	7	-0.007722008	2015	1	-0.007722008
	8	-0.007722008		2	-0.007722008
	9	-0.007722008		3	-0.007722008
	10	-0.007722008		4	-0.007722008
	11	-0.007722008		5	-0.007722008
	12	-0.007722008		6	-0.007722008
2013	1	-0.007722008		7	-0.007722008
	2	-0.007722008		8	-0.007722008
	3	-0.007722008		9	-0.007722008
	4	-0.007722008		10	-0.007722008
	5	-0.007722008		11	-0.007722008
	6	-0.007722008		12	-0.007722008

Year	Month	$Q_c(m,y)$	Year	Month	$Q_c(m,y)$
2016	1	-0.007722008		7	-0.007722008
	2	-0.007722008		8	-0.007722008
	3	-0.007722008		9	-0.007722008
	4	-0.007722008		10	-0.007722008
	5	-0.007722008		11	-0.007722008
	6	-0.007722008		12	-0.007722008
	7	-0.007722008	2019	1	-0.007722008
	8	-0.007722008		2	-0.007722008
	9	-0.007722008		3	-0.007722008
	10	-0.007722008		4	-0.007722008
	11	-0.007722008		5	-0.007722008
	12	-0.007722008		6	-0.007722008
2017	1	-0.007722008		7	-0.007722008
	2	-0.007722008		8	-0.007722008
	3	-0.007722008		9	-0.007722008
	4	-0.007722008		10	-0.007722008
	5	-0.007722008		11	-0.007722008
	6	-0.007722008		12	-0.007722008
	7	-0.007722008	2020	1	-0.007722008
	8	-0.007722008		2	-0.007722008
	9	-0.007722008		3	-0.007722008
	10	-0.007722008		4	-0.007722008
	11	-0.007722008		5	-0.007722008
	12	-0.007722008		6	-0.007722008
2018	1	-0.007722008		7	-0.007722008
	2	-0.007722008		8	-0.007722008
	3	-0.007722008		9	-0.007722008
	4	-0.007722008		10	-0.007722008
	5	-0.007722008		11	-0.007722008
	6	-0.007722008		12	-0.007722008

Table (I.7) $Q_d(m,y)$ values for the period (2011-2020)

Year	Month	$Q_d(m,y)$	Year	Month	$Q_d(m,y)$
2011	1	0.014805		7	-0.00437
	2	0.019155		8	-0.00234
	3	0.01765		9	-0.002415
	4	0.005015		10	-0.00511
	5	-0.008755		11	-0.00425
	6	-0.00686		12	0.0001
	7	-0.00437	2014	1	0.014805
	8	-0.00234		2	0.019155
	9	-0.002415		3	0.01765
	10	-0.00511		4	0.005015
	11	-0.00425		5	-0.008755
	12	0.0001		6	-0.00686
2012	1	0.014805		7	-0.00437
	2	0.019155		8	-0.00234
	3	0.01765		9	-0.002415
	4	0.005015		10	-0.00511
	5	-0.008755		11	-0.00425
	6	-0.00686		12	0.0001
	7	-0.00437	2015	1	0.014805
	8	-0.00234		2	0.019155
	9	-0.002415		3	0.01765
	10	-0.00511		4	0.005015
	11	-0.00425		5	-0.008755
	12	0.0001		6	-0.00686
2013	1	0.014805		7	-0.00437
	2	0.019155		8	-0.00234
	3	0.01765		9	-0.002415
	4	0.005015		10	-0.00511
	5	-0.008755		11	-0.00425
	6	-0.00686		12	0.0001

Year	Month	$Q_d(m,y)$	Year	Month	$Q_d(m,y)$
2016	1	0.014805		7	-0.00437
	2	0.019155		8	-0.00234
	3	0.01765		9	-0.002415
	4	0.005015		10	-0.00511
	5	-0.008755		11	-0.00425
	6	-0.00686		12	0.0001
	7	-0.00437	2019	1	0.014805
	8	-0.00234		2	0.019155
	9	-0.002415		3	0.01765
	10	-0.00511		4	0.005015
	11	-0.00425		5	-0.008755
	12	0.0001		6	-0.00686
2017	1	0.014805		7	-0.00437
	2	0.019155		8	-0.00234
	3	0.01765		9	-0.002415
	4	0.005015		10	-0.00511
	5	-0.008755		11	-0.00425
	6	-0.00686		12	0.0001
	7	-0.00437	2020	1	0.014805
	8	-0.00234		2	0.019155
	9	-0.002415		3	0.01765
	10	-0.00511		4	0.005015
	11	-0.00425		5	-0.008755
	12	0.0001		6	-0.00686
2018	1	0.014805		7	-0.00437
	2	0.019155		8	-0.00234
	3	0.01765		9	-0.002415
	4	0.005015		10	-0.00511
	5	-0.008755		11	-0.00425
	6	-0.00686		12	0.0001